Decontamination of Test Range Metal Debris using a Transportable Flashing Furnace

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FRONT MATTER

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Acronyms

ACC	Air Combat Command
AFB	Air Force Base
AFCEF	Air Force Center for Environmental Excellence
AFMAN	Air Force Manual
AFMC	Air Force Material Command
AIHA	American Industrial Hygiene Association
AMC	Army Material Command
BAE	British Aerospace Engineering
BRAC	Base Realignment and Closure
CINCLANT-FLT	US Navy Commander in Chief, Atlantic Fleet
CISWA	Commercial and Industrial Solid Waste Incinerators
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CWP	Contaminated Waste Processor
DOD	Department of Defense
DOE	Department of Energy
TFF	Transportable Flashing Furnace
EDE	El Dorado Engineering
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
FORSCOM	Army Forces Command
FUDS	Formerly Used Defense Site Program
ITRC	Interstate Technology Regulatory Council
MCAS	Marine Corp Air Station
MKM Engineering	Company Title
MLI	Munitions List Item
MPPEH	Material Presenting Potential Explosion Hazard
NAVSEA	Naval Sea Systems Command
NOC	Network Operations Center
NO_x	Oxides of Nitrogen
NWSC	Naval Surface Warfare Center
NWS	Naval Surface Warfare
OB/OD	Open Burning/Open Detonation
O_2	Oxygen
PPM	Parts per million
RCRA	Resource Conservation and Recovery Act
SFW	Special Fused Weapons
SLI	Strategic List Items
SUBASE	Naval Submarine Base
TRADOC	Army Training and Doctrine Command
TB	Technical Bulletin

UXO	Unexploded Ordnance

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ABSTRACT

Debris collected at military test ranges vary in type, size, and density. Currently, this material is decontaminated to a 3X level by cleaning and visual inspection. In order to be classified to 5X level and released to the public without restriction, it must be thermally treated. As thermal decontamination ovens are primarily fixed installations, transportation costs of potentially contaminated material are prohibitive.

To overcome this, EDE has developed the Transportable Flashing Furnace (TFF) by adapting contaminated waste processing technology to a standard 48-ft. trailer configuration. The TFF can be easily deployed for high-volume, repeatable certifiable 5X decontamination. EDE has designed, fabricated, and installed three TFF's for non-test range applications for Army, Navy, and Air Force installations.

The demonstration is focused on test range applications. It was separated into three phases. Phase 1 demonstrated that the TFF can be used to flash range material to a 5X level. In addition, an effective basket design was established which would structurally withstand the heat, contain any molten aluminum created during the flashing cycle, and allow efficient heating of the material.

Phase 2 demonstrated that the heat cycle does not vary significantly based on the density of the materials flashed. Explosive treated coupons were used to verify that explosive material would be eliminated by the flashing cycle. These coupons were sent to a laboratory and analyzed. They were completely clean from any explosive residue providing additional confidence that this material is correctly classified as 5X.

Phase 3 dealt with establishing operating parameters which would maximize throughput. Labor, materials, cycle times, and all necessary operating parameters were determined. A reliable heat soak cycle time was developed that assures metal decontamination and eliminates the costs and problems associated with instrumenting each load.

Emissions levels were tested to verify that they are insignificant and will have little or no impact on siting the TFF. As expected, all emissions were below established limits. The demonstration confirmed that the TFF can be used to decontaminate range scrap to a 5X level efficiently, effectively, and economically.

With the appropriate operating parameters and operating at the maximum throughput, the TFF can flash 4375 tons of scrap per year. Range scrap is comprised of mostly steel. With loads of primarily steel, the total overall cost, including all variable costs and amortized capital costs, of decontaminating this material is $86 per ton. However, with some scrap piles, there will be a significant amount of aluminum. Salvagers are currently buying scrap aluminum at a price 40 times greater than steel. If scrap loads are made up of 10 percent aluminum, total overall costs for decontaminating this material reduce to $46.60 per ton.

1 INTRODUCTION

1.1 Background

The largest quantities of debris collected during the clearance of military test ranges are not live munitions; but, parts and pieces of munitions that may or may not have trace quantities of explosive contamination. The collected debris, including “target debris”, varies in size from very small fragments to very large fragments and consists primarily of steel, with some brass and aluminum, and small portions of other materials. In a typical range clearance operation, the debris is located, collected, and stored near the test range.

Decontamination to a 3X level can be obtained by cleaning and visual inspection; however, blind areas, joints, cracks, voids, etc. can harbor residual energetic materials. Transfer documents for decontaminated metals must attest to the inspection of the materials and certification that it bears no explosive material. 3X material that is decontaminated by thermal treatment is classified 5X and can be freely released to the public without restriction. Since, up to now, thermal decontamination ovens have been fixed installations, and costs of transporting and treating contaminated debris have been prohibitive, the debris has remained unprocessed and stored locally, often buried on-site. In some instances, this leads to costly environmental investigations of these activities.

For transportability purposes, El Dorado Engineering (EDE) has adapted the well-established contaminated waste processing technology onto a standard 48-foot trailer configuration. The Transportable Flashing Furnace (TFF) technology can be easily deployed to the field for high-volume, repeatable, certifiable 5X decontamination. It was necessary to perform the required testing to optimize operating parameters for complete thermal treatment and to maximize throughput.

It is noted that with initial operation using the TFF in the cleanup of Kaho’olawe, Hawaii, a thermal criteria of 1000^{o}F for 15 minutes was used. This was based on the 5X definition long established for chemical munitions residue known to effectively treat both explosives and chemical agents. There were no established criteria for conventional munitions residues. The Navy adopted a lower limit temperature limit of 650^{o}F, based on a literature review and limited testing. EDE did not attempt to establish the lowest possible criteria, but to validate the use of the lower criteria established by the Navy. EDE was able to conclusively demonstrate by the use of explosive contaminated coupons that the 650^{o}F limit as previously established by the Navy was more than adequate. It is estimated that lowering this limit doubles production and cuts fuel costs in half. Maintenance costs are reduced by more than 50% as basket life will be greatly extended.

1.2 Objectives of the Demonstration

The primary objective of this demonstration was to clearly demonstrate that the TFF can effectively, efficiently, and economically be used to flash military test range scrap to 5X condition. This allows disposition of this material by direct sale to metal salvagers. The demonstration included the following:

1. Demonstrate that the material reaches sufficient temperature (650^{o}F) for total decontamination of metal parts and by the placement of laboratory prepared explosive coupons, demonstrate that this temperature is sufficient to completely decontaminate metals.
2. Demonstrate that a basket/tray design can be optimized to process a wide variety and density of actual materials recovered from an Air Force test range. This included being able to handle metals such as aluminum that may become molten during the flashing operation.
3. Demonstrate that target debris can be flashed effectively.
4. Determine whether or not it is more advantageous to instrument each load with thermocouples to verify that all material has reached the temperature threshold of 650^{o}F or that a standard heat soak time can be established that exceeds the worst case heat soak time, without instrumenting each load, and still guarantee that the temperature threshold is reached.
5. Measure all parameters used to determine cost of this operation including fuel usage, labor requirements, and process times.
6. Monitor air emissions to verify that the air emissions will not have an impact on siting the TFF based on environmental restrictions.

Advantages of using the TFF to support range cleanup include:

- Transportability of the TFF; eliminating the need to transport 3X material
- Variety of range scrap size and configurations can be processed
- Emissions are minimal
- Eliminates OB/OD

The demonstration concentrated on ammunition items that contained high-explosive fillers and propellants and excluded such chemical fillers as pyrotechnics, flare/smoke compositions, lethal/non-lethal agents, depleted uranium and similar items.

1.3 Regulatory Drivers

Specific regulations, directives, and accident history considerations have created a critical need for this technology both from a personnel safety and an environmental perspective. Refer to the following drivers:

1. TB-700-4. “Decontamination of Facilities and Equipment.” October 31, 1978.

   The Army Technical Bulletin prohibits shipping potentially explosive contaminated materials from a military facility without thermal treatment. The Air Force and Navy have not issued regulations but recognizes the seriousness of safety issues of these materials. “No metal scrap which has been contaminated with explosives or harmful chemicals shall be released for general use unless flashed and certified to be free of hazardous contamination.” Paragraph 3-10b.

2. Letter from the Commander, Naval Facilities Engineering Command. 2 May 2003.

   “Due to two recent explosives mishaps associated with munitions, which were certified as inert, reference (a) identified and recommended certain actions and reviews due to their identification of a declining trend in the management and processing of munitions residue. In addition, reference (b) provided a warning to those personnel involved in munitions response.”

3. Memo from Naval Ordnance Safety and Security Activity. 2 May 2003.

   “Thermal processing: The most effective way to ensure that Material Presenting Potential Explosive Hazard (MPPEH) is inert is to heat the article to a temperature above the decomposition temperature of any potential explosives residue. A flashing furnace or oven should be used for this process.”

4. Supposedly inert material from range cleanup at Kaho’olawe, Hawaii exploded in their flashing furnace in 2004 and avoided a potential accident if the material had been released directly.

5. OPNAV Instruction 3500.39A, Operational Risk Management (ORM).

   “All activities that handle munitions residue shal conduct a stand-down to review procedures involved with the inert certification and disposal of these items. Under no circumstances, should UXO be cut with a torch during demilitarization or salvage operations.

Environmental regulations also favorably drive this process. Reference 40 CFR 264 RCRA and CISWI clean air act.

6. Navy legal opinion rendered by Karen Heckelman, Command Counsel (Navy)

   Question: Are Army flashing furnaces subject to the "commercial and industrial solid wasted incinerators' (CISWI) Clean Air Act Regulations?

   Answer: If the flashing furnace only handles material that does not qualify as RCRA "solid waste," then the furnace is not subjected to the CISWI Clean Air Act regulations. "Processed scrap metal" that is being recycled is excluded from the definition of "solid waste." Scrap metal from unused munitions, former munitions production equipment, and cartridge cases from fired munitions may qualify as "processed scrap metal."

7. There are de minimis limits in many states that define an emission threshold below which operations do not require air permits.

8. The Department of Defense has at each Global Demilitarization Symposium in the last several years reiterated a commitment to eliminate open burning. Therefore, flashing by open burning has virtually been eliminated.

9. DoD Directive 5160.65, "Single Manager for Conventional Ammunition," November 17, 1981.

10. DoD Manual 5160.65M, "Implementing Joint Conventional Ammunition Policies and Procedures," Chapter 13, Paragraph F, "Demilitarization and Disposal – Developing Technical Procedures and Instructions." April 1989.

    DoD 5160.65 is implemented within Military Services by 5160.65M. It is recognized that range clearance operations are not demilitarization per se but the decontamination of metal parts during range clearance is in many respects very similar to the concluding operation in a demilitarization operation at a depot, ammunitions plant, or arsenal. The purpose for both is to decontaminate materials to permit their inspection and subsequent certification as being free of explosive contamination. Paragraph F sites as one of its objectives to "maximum attainable recycling of resources used in ammunition." This demonstration is support of range clearance operations is consistent with similar equipment requirements in support of demilitarization operations.

11. DODI 4715.4, Pollution Prevention.

12. DOD 4160.21-M and DOD 4160.21-M-1, “Defense Demilitarization Manual.” October 22, 1981.

    Failure to decontaminate scrap materials recovered from ranges to a 5X level impacts greatly upon the installation’s ability to recycle the metal. Under certain exceptions, contaminated (3X) material may be transferred to select recipients having previous authorization to receive material in a contaminated condition. DODI 4715.4, establishes procedures requiring the establishment of installation recycling programs where cost effective. Attempts to recycle metal scrap recovered from ranges in a contaminated condition (3X) would greatly impact upon the recycling of the material. DODI 4715.4 also defines “Excluded Materials” in definition 9. The definition states “Excluded materials may not be sold through a qualified recycling program, and the proceeds from their sale shall not be returned to a qualified recycling program. Excluded materials include, but are not limited to: “Subparagraph k. states “All Munitions List Items (MLI) and Strategic List Items (SLI) as defined in DoD 4160.21-M-1, except firing range expended brass and mixed metals gleaned from firing range clean-up.”

These drivers prohibit explosive-contaminated metal from being released directly to the public and restrict the use of open burning to be used as a flashing operation. The drivers conveniently allow the TFF to be operated without obtaining special environmental permits. Its emissions are below de minimis requirements. Refer to Section 4.3.4.

1.4 Stakeholder/End-User Issues

All DOD installations involved with ammunition have a basic requirement for a method of decontaminating materials from a 3X to a 5X state. Current demilitarization practices at facilities operated by all four military services render the ordnance items incapable of functioning in its designed manner but may not necessarily rid the item of all explosive material. Thus, the need for a flashing furnace technology to remove all explosive materials is required.

From a study performed by the Joint Ordnance Commander Group and the Demilitarization and Environmental Subgroup, it is estimated that there are currently sixty installations in the United States that operate active test ranges. Table 1 lists these installations by military service branch; Table 2 lists them by state; and Table 3 sorts them by region.

Table 1: Complete listing of all DOD installations which have active test ranges and could utilize this technology to clean their test ranges.

U.S. Army			**Other Services**
FORSCOM	AMC[x]		U.S. NAVY
Fort Bragg, NC	Aberdeen Proving Ground, MD		NAVSEA
Fort Campbell, KY	Dugway Proving Ground, UT		
Fort Carson, CO	Picatinny Arsenal, NJ		EOD Tech Div Indian Head, MD
Fort Dix, NJ	Redstone Arsenal, AL		NOC Port Hadlock, WA
Fort Drum, NY	White Sands MR, NM		NWSC Crane, IN
Fort Hood, TX	Yuma PG, AZ		NWSC Dahlgren, VA
Fort Hunter Liggett, CA	National Guard Bureau		NWSC Indian Head, MD
Fort Irwin, CA			CINCLANT-FLT
Fort Lewis, WA	Camp Atterbury, IN		
Fort Polk, LA	Camp Ripley, MN		NWS Charleston, SC
Fort Riley, KS	Camp Shelby, MS		NWS Earle, NJ
Fort Stewart, GA	Fort Chaffee, AR		NWS Yorktown, VA
Yakima TC, WA	Fort Indiantown, PA		SUBASE Kingsbay, GA
TRADOC	Fort McClellan, AL		U.S. Air Force
	Fort Pickett, VA		
Fort Bennion, GA	Camp Navajo, AZ		
Fort Bliss, TX			ACC
Fort Bliss, VA			Cannon AFB, NM
Fort Huachuca, AZ			Holloman AFB, NY
Fort Jackson, SC			Shaw AFB, SC
Fort Knox, KY			AFMC
Fort Leonardwood, MO			
Fort McClellan, AL			Edwards AFB, CA
Fort Rucker, AL			Eglin AFB, FL
Fort Sill, OK			Hill AFB, UT
West Point, NY			Kirtland AFB, NM
			AFSPC
			Patrick AFB, FL
			Vandenberg AFB, CA
			U.S. Marine Corps
			Camp LeJeune, NC
			MCAS Beaufort, SC
			MCAS Cherry Point, NC
			MCAS Yuma, AZ
[x] Excludes depot type installations and ammunition plants/arsenals			

Table 2: Breakdown of DOD installations by state

	ARMY				NAVY			AIR FORCE			MARINE	
	FORSCOM	TRADOC	AMC	NGB	CINCLANT-FLT	NAVAIR	NAVSEA	ACC	AFMC	AFSPC		TOTAL
Alabama		2	1	1								4
Arizona		1	1	1							1	4
Arkansas				1								1
California	2					1			1	1		5
Colorado	1											1
Florida									1	1		2
Georgia	1	1			1							3
Indiana				1			1					2
Kansas	1											1
Kentucky	1	1										2
Louisiana	1											1
Maryland			1			1	1					3
Minnesota				1								1
Mississippi				1								1
Missouri		1										1
New Jersey	1		1	1								3
New Mexico			1					2	1			4
New York	1											1
North Carolina	1										2	3
Oklahoma		1										1
Pennsylvania				1								1
South Carolina		1			1			1			1	4
Texas	1	1										2
Utah			1						1			2
Virginia		1		1	1	1						4
Washington	2					1						3
												60

Table 3: Breakdown of DOD installations by geographical area

	Army	Navy	Air Force	Marine Corps	Total
NE	7	5			12
SE	10	2	3	3	18
NC	3	1			4
SC	7				7
NW	2	1			3
SW	8	1	6		16
TOTAL	37	10	9	4	60

NW	NC	NE
3	4	12
SW	SC	SE
16	7	18

Results of this demonstration will provide these end-users with an understanding of the technical, logistical, and financial impact of applying the TFF technology for their decontamination requirements.

Besides test ranges, the TFF has application in related programs associated with BRAC and FUDS remediation activities. Not only can munition fragments and target debris be processed, but building materials and explosive processing equipment such as TNT melt kettles can be decontaminated. The TFF operations at Ravenna were specifically targeted to the decommissioning of explosive manufacturing and melt/ pour facilities. The use of the TFF at Kaho'olawe was part of the largest FUDS remediation projects accomplished by DOD to date.

In addition, the TFF has potential for a wide application in demilitarization programs. A TFF was recently delivered to Anniston Munitions Center for use in the demilitarization of rocket motors. The propellant and explosive items are removed from the rocket motors for recycling and the metal parts are flashed prior to recycling metal. The TFF has application to flash large projectile and bomb bodies where the explosives are removed either by steam-out or microwave melt-out and sold to the mining explosive industries. One of the major benefits of the use of the TFF for demilitarization is that by providing a method of decontaminating munition metal parts, it allows for recycling of the energetic materials rather than disposal of the items to be demilled.

2 TECHNOLOGY DESCRIPTION

2.1 Technology Development and Application

Many U.S. Army Depots and load lines possess quantities of 3X explosive contaminated scrap. In response to increasingly stringent environmental regulations in the late 1970's and early 1980's, the Army developed a small, simple flashing furnace, see Figure 1. This stationary unit employed a refractory car bottom that moved in and out of the furnace to facilitate loading and unloading. A typical application might include flashing 750 lb. bomb bodies from wash out or melt out operations. In order to sell the metal debris as scrap, the bomb bodies had to first be thermally processed to a 5X level of decontamination.

Because of mounting public and environmental regulatory pressure, it was proposed that explosive-contaminated combustible materials be added to the Army's flashing furnace feed stream. Many of these materials burned all day long in the open, generating thick, black smoke. Due to poor burn qualities, these materials often had to be re-burned. To process combustible explosive contaminated wastes, modifications such as greater combustion air input equipment, an unfired afterburner, and a complete pollution control system were added to the flashing furnace. A larger version of the furnace was also designed to provide greater throughput and a capacity to decontaminate 20-foot sections of pipe. This system became known as the Contaminated Waste Processor (CWP).

Figure 1: The US Army simple flashing furnace with a rolling hearth (processing 750 lb. bomb shells)

The CWP was intended to provide not only flashing but also combustible waste burning. All Army CWP installations were stationary. Upon a review of the system, El Dorado

Engineering (EDE) ascertained that by eliminating the combustible waste processing capabilities, the flashing furnace technology could be made transportable. Such a system would be ideal for field-deployed locations to service small or temporary needs that could not justify a larger, multi-role, fixed installation.

The system used for this demonstration is the Transportable Flashing Furnace (TFF) designed by EDE to meet the following specifications:

- Transportability: complete system highway transportable within a 48’ trailer
- Easy loading of large, heavy or awkward material: carbottom rollout
- Heat cycle time: 45 to 90 minute depending upon load size and type
- Operating temperature range: 1000°F - 1600°F
  This demonstration showed that for flashing range scrap, there is no advantage gained by operating the furnace at a higher temperature. The operating temperature should be set at 1000°F for flashing range scrap material.
- Load capacity: 10,000 lbs. per batch
- Throughput: 2 tons/ hour, typical
- Nominal internal dimension: 5' high x 7' wide x 17' long.
- Burners: oil-fired dual burners with propane pilots; 6M BTU/hr capacity
- Insulation: ceramic wool allows rapid heat up and cool down
- Cooling air input system: for rapid cool down
- Unfired afterburner: to minimize emissions
- Controls: main controls on trailer; pendant mounted controls for remote operation
- Instrumentation: ability to record and verify each load temperature
- Field mounting: required to set up and take down within one day each
- Electric power source: stand alone generator for remote field operations, optional
- Fuel tank skid: for remote field operations, optional

Figure 2: Disassembled TFF ready for shipping

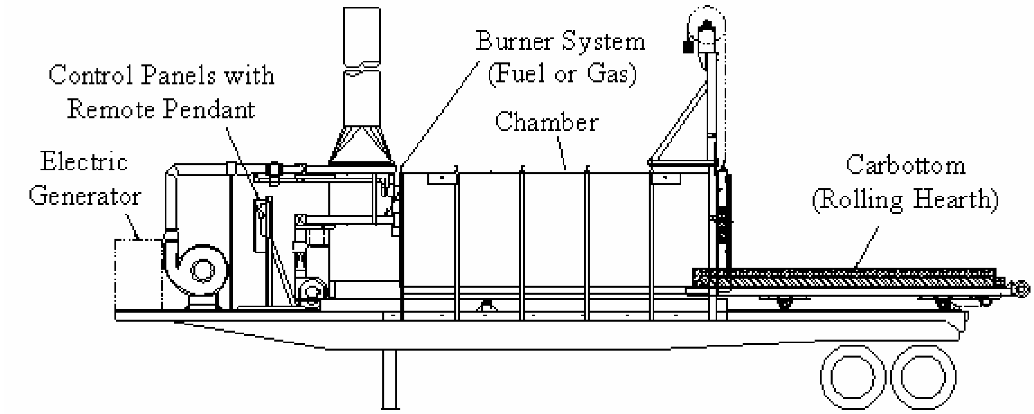

Figure 3: TFF Elevation View (fuel skid not shown)

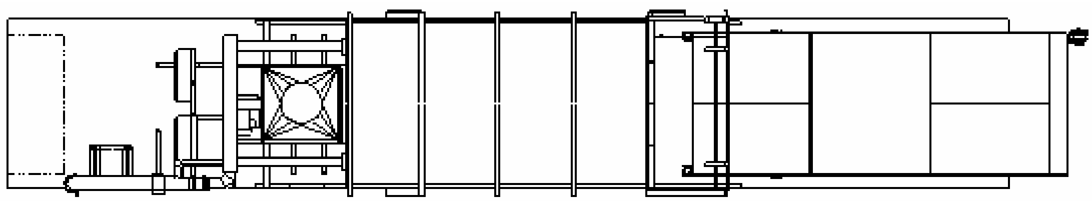

Figure 4: TFF Plan View (fuel skid not shown)

2.2 Previous Testing of the Technology

EDE has designed, fabricated, and installed three Transportable Flashing Furnaces (TFF) for related, non-test range applications, for Army, Navy, and Air Force installations.

1. The first TFF was installed at Ravenna Army Ammunition Plant. Under contract with the Army, MKM Engineers was dismantling explosives contaminated equipment and facilities to support closure of a plant that had been used in munitions manufacturing operations. The EDE TFF was installed and has operated at Ravenna since the spring of 2000. Due to the low emissions from the TFF, environmental regulators deemed the TFF's emissions as "insignificant" and did not require a RCRA permit or an air permit in the State of Ohio.

   For more information, contact: Mark Vess, MKM Engineers, 8451 State Route 5, Bldg. 1038, Ravenna, Ohio. 44266, Telephone: 330-358-2920

2. A second TFF was furnished to Eglin Air Force Base (AFB), Florida for processing small arms ammunition. This unit used removable strongboxes (burn kettles) to

process the explosive wastes that were loaded onto the car bottom furnace. Since this application was for actual ordnance classified as a hazardous waste rather than merely contaminated material, it was operated under Eglin AFB Subpart X RCRA permit. It should be noted that only the strongboxes required permitting and not the TFF. The TFF was considered as a heat source to the strongboxes and did not require its own permit to operate.

For more information, contact Ed O'Connell, Eglin Air Force Base, AACEM-FQ-3EMC, 501 De Leon Street, Suite 101, Bldg. 696, Eglin Air Force Base, Florida 32542, Telephone: 850-882-4713.

3. A third unit was provided to the contractor Parsons/UXB for use in the cleanup of Kaho'olawe, Hawaii. This application closely resembles active military test range operations as it involves final cleanup of a former Navy Test Range. This TFF system is accepted as a non-RCRA process without an air permit.

   For more information, contact: Joe D'Aquilla, Parsons/UXB, 220 Kaho'olawe Avenue, Bldg. 371A, Pearl Harbor, HI 96860, Telephone 808-471-4303.

2.3 Factors Affecting Cost and Performance

The principal factors affecting cost and performance include the following:

1. Instrumentation
2. Process Time
3. Manpower
4. Fuel
5. Basket Selection
6. Scrap Weight
7. Basket Location
8. Set-up of the TFF
9. Safety Considerations During Operations

2.3.1 Instrumentation

EDE developed two hypotheses which would ensure that the material is correctly classified as 5X. These are summarized as follows:

- Instrumenting Each Load with Thermocouples. When the material reaches 650^{o}F, the material will be allowed to heat soak for 10 minutes. This would be implemented if there was significant batch-to-batch variation in the time and fuel required to flash the material.
- Reliable Worst-Case Heat Soak. However, if batch-to-batch heat soak times do not greatly vary, instrumentation can be eliminated and a standard, reliable heat soak time determined.

There are advantages and disadvantages to both cases. With instrumentation, operators would know exactly when the material reaches the appropriate temperatures. Therefore, heat-up time and fuel would be conserved. However, there are problems associated with instrumentation:

- Longer preparation times
- Additional equipment is needed
- Additional maintenance activities are required

This demonstration showed that process times based on density varied, but not significantly. Rather, random effects, most likely caused by placement of the scrap items, were the cause of differing heat-up times and correlating fuel consumption. A standard, reliable heat soak time was developed, see Section 4.3.3 for complete analysis.

2.3.2 Process Time

The process time includes the following:

1. Loading and unloading the Carbottom
2. Purge Cycle Time
3. Heat Time to 650^{o}F
4. Heat Soak Time
5. Cooling Time

The time to load and unload the carbottom was monitored during the second phase of testing. Load time includes the time it takes the forklift to load 2 baskets onto the carbottom; roll the carbottom in; and close the door. The average time it took to load the carbottom was found to be 4 minutes with little variation. Unload time was similar.

Prior to starting the burners, a two-minute purge cycle is necessary. This is designed to purge the fuel lines prior to lighting the pilot lights and burners.

Immediately following the purge cycle, the heat cycle begins. The heat cycle is defined as the time the burners start until the last thermocouple reached 650^{o}F. The heat time for flashing range scrap should be 40 minutes. This was developed from Phase 2 and 3 testing results. This will ensure that all material will be decontaminated to a 5X level.

The Heat Soak Time lasts for 10 minutes. Initially, the heat soak involved leaving the burners on for 10 minutes after the last thermocouple reached 650^{o}F. During Phase 1 testing, it was determined that the burners did not need to be on during the heat soak. The temperature inside the furnace was ample to keep the material temperature above the 650^{o}F limit, Reference Section 4.3.1 for complete analysis.

After completion of the 10 minute heat soak, the cooling blowers were turned on until the temperature of the furnace cooled to 600^{o}F. The average cooling time per test was 5 minutes with some variation.

Process Time is summarized as follows:

Table 4: Process Time for each load in minutes

Load/ Unload Time	8
Purge Cycle	2
Heat Time to 650^{o}F	40
Heat Soak Time	10
Cool	5
Total	**65**

2.3.3 Manpower

The required manpower was monitored and the following recommendations made. In order to maximize throughput and for operator safety, 2 operators should be used to operate the TFF. The TFF is designed for simple, easy use. The carbottom is controlled by a pendant located on the side of the trailer. All other necessary controls and alarms are located on the control panel providing simple inclusive control for one operator. The other should be a skilled forklift operator, responsible for loading and unloading the carbottom.

For test range scrap, EDE has recommended that at least one of the operators be either EOD certified or a civilian UXO technician. The general purpose of the flashing furnace is to remove small quantities of explosive that are in crevices, cracks, etc., or to process small munitions components that were not expended. The design of the operation has been reviewed for the operator being safe for up to a one-pound high order detonation. However, having high-order detonation is not meant to be the routine practice of the furnace. Previous testing has shown that up to full up 20 mm HEI rounds can be processed in the furnace utilizing a strong box. Thus, if materials are highly suspected of containing live ammunition, a strong box should be utilized. The other materials should be screened to the point that the UXO technician can know that there would be no highly explosive charges greater than one pound that could be confined and able to detonate as a high order detonation.

Figure 5: A skilled forklift operator is necessary to load and unload the baskets to and from the carbottom.

In order to maximize throughput, the forklift operator should stage another load for flashing, while material is in the furnace being flashed.

This presents another issue: keeping the baskets loaded. Two additional laborers should be utilized to load the baskets with the scrap. They should also be responsible for preparing previous loads for removal from the site and ensuring that fuel levels are maintained properly.

Required manpower rates and costs are summarized as follows:

Table 5: Manpower Rates and Estimated Costs

Description	Quantity	Rate	Price
2 operators/wk	80 hrs	$40/hr	$3200/wk
2 laborers/wk	80 hrs	$15/hr	$1200/wk

2.3.4 Fuel

The TFF requires propane fuel to fuel the pilot lights and number 2 fuel oil for the burners. Fuel consumption was monitored throughout testing. Spare propane tanks should be located on site to avoid delays. Tanks should be replaced every 2-3 days.

Each heat cycle requires 29.5 gallons of fuel. In that heat cycle 2.5 tons of scrap is processed. Each cycle takes 65 minutes. From this information, the following fuel consumption rates are summarized.

Table 6: #2 Fuel Oil Consumption

Amount of Fuel (gal)/ test	29.5
Amount of Fuel (gal)/ ton	11.8
Amount of Fuel (gal)/ hour	27.2

Fuel tanks for the TFF have varied in size from the 400 gallon tank which was used for this demonstration to the 10,000 gallon tank used at Kaho'olawe that allows for long operating periods without refueling. Users of this technology should evaluate their situation and needs prior to selecting an optimal fuel tank.

2.3.5 Basket Selection

Phase 1 of testing dealt with the selection of an effective basket which would be structurally sound and allow efficient heat transfer to the contents of the baskets. Upon initial testing, it became apparent that the baskets needed to account for the molten material, specifically aluminum. Basket CC1, see Figure 6, was the basket which best exhibited the qualities of maintaining structural integrity and the ability to contain molten aluminum, while still allowing efficient heat transfer to the basket's contents. This basket was designed by EDE. Presently, the cost of this basket is $4,100 and associated tray is $2,366. At least 8 baskets and 4 trays should be purchased for a full-scale

operation which would maximize throughput rates. Reference Section 4.3.1 and Appendix A.2 for all information on basket selection.

Figure 6: Basket CC1 with 120 mm tank rounds

2.3.6 Total Basket Weight and Location

Many basket parameters were tested to determine how best to increase the amount of material that can be flashed while minimizing the fuel. It was noticed that loads higher in the carbottom heat slightly faster than loads closer to the floor. This basket is propped on a tray to position the range scrap material in this optimum position. Best results are found when 2 baskets are filled with 2500 lbs of range scrap or maximum volumetric capacity for low-density materials, See Figure 7. These baskets are placed on the carbottom, one located 1 ft from the door; the other located 10 ft from the door.

Figure 7: Two baskets each filled to maximum volumetric capacity of range scrap each are flashed in the same heat cycle.

2.3.7 Set-up of the TFF

It is noted that some ranges have large stockpiles of scrap in one particular location. They would transport the TFF to this location and leave it there for a substantial period of time until all material is processed. Others have smaller stockpiles of scrap at many locations. For these ranges, the TFF would need to be transported to different areas more frequently. The TFF is designed to be able to be taken down and set-up in one day.

In an attempt to reduce this time, EDE has designed a new door which does not require disassembly prior to transporting the TFF. In addition, plans for future TFF's include a redesign of the stack which would still further reduce take-down and set-up time.

2.3.8 Safety Considerations During Operations

When using the TFF for processing test range scrap, EDE recommends that at least one of the operators be EOD certified or a civilian UXO technician. The purpose of the flashing furnace is to remove small quantities of explosive that are hidden in crevices, cracks, etc. or to process small munition components that were not expended in testing. The TFF is supplied with a control pendant with standoff distance such that the safety of the operator is maintained for up to a 1 lb high order detonation. This however is not meant to be the routine practice of the furnace to have high order detonations of this magnitude.

Previous operations have shown that up to full-up 20 mm HEI rounds can be processed in the furnace utilizing a strong box. (This operation has been performed at Eglin AFB for a number of years and testing of the strong boxes and on full-up rounds was specifically excluded from these tests.) Thus, if materials are suspected of containing live ammunition, a strong box should be utilized.

Range scrap materials should be screened to the point that the EOD or UXO technician can know that there would be no explosive charges greater than one pound that could be confined and able to detonate as a high order detonation. Although it is very difficult to screen materials for the presence of explosives, it is not considered difficult for an EOD or UXO technician to assure that materials with potentially a 1 lb contained charge of greater are not placed in the TFF.

In processing 8 million pounds of material at Kaho'olawe, they experienced a large high order detonation. The operators were not injured in any way. The TFF received minor damages but was repaired and returned to normal operation within one week. Incidents such as this, although rare, should not be unexpected. Smaller detonations and unconfined explosive materials present burned without incident.

EDE strongly recommends against any attempts to vent and process large explosive charges in the TFF, as explosives are unpredictable and this would introduce risk to the operators. EDE has for many years designed and supplied Explosive Waste Incinerators where large items are punched or vented. However, the barricade structure for these permanent installations are substantial such that operators are not at risk, should the items go high order and only the equipment is placed at risk.

2.4 Advantages and Limitations of the Technology

The EDE TFF offers the following significant advantages:

- Transportability
- Ease or lack of permitting requirements
- Operational in remote, isolated, dispersed or geographically difficult terrain
- Adaptable for supporting a wide variety of operations including UXO clean-up

It is noted that it is extremely difficult to define a monetary cost benefit for using this technology as currently there is no technology being used for thermally decontaminating range scrap and this material is being stored indefinitely. There has been some effort to shred or otherwise size-reduce these materials and perform visual inspections. These operations are considerably more costly than thermal treatment and still do not guarantee explosive-free materials.

There are documented cases of this type of 3X material being sent from military installations to recycling facilities which caused fatalities and accidents by people handling materials they thought were inert. In addition, there is considerable environmental liability. All DOD agencies operating or closing test ranges now recognize the seriousness and magnitude of range contamination and material management. EDE was involved in a project at Nellis Air Force Base where this material had been buried at five sites in the desert. Nellis AFB was required to perform an unexploded ordnance sweep of each area, remove all desert tortoises and then drill, place, and operate ground water monitoring wells at each site. This risk only grows worse with time. Treating and removing contaminated debris will be a major reduction of risk and liability.

The other alternative is OB/OD. While it might be argued that this is cheaper, it is clear that it is not environmentally sound or efficient. There is no way of knowing whether or not all material has reached 650^{o}F and was completely decontaminated. The military has already expressed its opinion regarding the elimination of all OB/OD, reference section 1.3.

3 DEMONSTRATION DESIGN

3.1 Performance Objectives

The test program was organized into three phases, each with its own performance objectives. Demonstration efforts for each phase include the following objectives: (Refer also to Table 7)

Phase 1: Evaluate process effectiveness for 5X decontamination

The purpose of Phase 1 is to demonstrate the ability of the TFF to effectively thermally decontaminate range scrap to 5X criteria. The following objectives were evaluated:

1. Ability of the TFF to process range scrap material to 5X condition.
2. Ability of the TFF to handle a wide variety of sizes and shapes of range material.
3. Impact of different basket/ tray designs for operational effectiveness.
4. Impact of location of the material in the furnace on the TFF heat cycle.

Phase 2: Investigate the optimization of process parameters

The purpose of Phase 2 is to investigate areas of process optimization to improve operational efficiency of the TFF by:

1. Monitoring the heat-up time required for loads of various densities.
2. Monitoring the labor required to perform TFF operations.
3. Developing procedures to optimize throughput of target debris.
4. Verify that Flashing Cycle eliminates explosive residue on explosive-treated coupons.

Phase 3: Investigate cost and throughput parameters

The purpose of Phase 3 is to gather operating data so as to define and analyze cost and throughput parameters for the TFF.

1. Obtain the required information to define operating cost and throughput to thermally decontaminate range scrap/ target debris by monitoring fuel consumption, instrumentation time, maximum process time, required manpower.
2. Determine whether or not it is more advantageous to instrument each load with thermocouples or develop a set time based on a worst case heat time.

Table 7: Performance Objectives

Type of Performance Objective	Primary Performance Criteria	Expected Performance Metric	Actual Performance Objective met
Phase 1			
Quantitative	Ability of TFF to 5X range scrap material	>650^{o}F for 10 min	Yes
	Ability of TFF to handle wide variety of shapes and sizes	>650^{o}F for 10 min	Yes
	Evaluate Basket Designs to optimize heat cycle by monitoring and comparing the following:		
	Time Required to heat loads to 650^{o}F	40 min	Varies slightly for differing baskets and materials. CC1 32 min
	Fuel Usage	30 gal per 2500 lb	Varies for differing baskets. CC1 average 22.4 gal per 2500 lb
	Basket Cost	$4,000	Varies for differing baskets CC1 – $4,000 (basket) $2,000 (tray)
Quantitative	Basket Structural Integrity	Operator Acceptance	Varies for different baskets. Yes for CC1
	Basket molten material containment	Operator Acceptance	Varies for different baskets. Yes for CC1

Phase 2			
Qualitative	Labor requirements to maximize throughput	2 labor (80 hrs/ wk) Skilled operator (40 hr/wk) Skilled forklift operator (40 hr/wk)	Same as Expected
Quantitative	Fuel consumption per weight scrap (gal/ton)	12	7.96
	Monitor Heat-up time required for loads of various densities	Mean Heat up Time (min): High-30 Medium-33 Low-36	High- 24.3 Medium- 29.3 Low- 27.7
	Explosive Coupon Residue	100 % clean	100 % clean
Phase 3			
Quantitative	Fuel Consumption Worst Case and Mean	worst case-30 gal/5000 lb (27.7 gal/hr) mean-20 gal/5000 lb (18.5 gal/hr)	Worst case- 29.5 gal/ 5000 lb (27.2 gal/hr) Mean- 20 gal/ 5000 lb (18.5 gal/hr)
	Monitor cycle (time) required for TFF operations to develop realistic throughput operations		
	Instrumentation Time	>5min/TC (4 TC/load)	5 min/TC (4 TC/Load) 20 min/load
	Process Times	(no instrumentation) Mean-70 min Worst Case-80 min	Mean- Worst Case-62 min
	Total Throughput	40,000 lb/8-hr day	30 – 35K lb per 8-hr day

3.2 Selecting Test Site

The demonstration efforts were performed in conjunction with Air Force range management and BAE Systems at Eglin Air Force Base (AFB), Florida. The demonstrations were held on Field 5 as selected by Eglin range management. The Transportable Flashing Furnace (TFF) currently located at Eglin Air Force Base was used to conduct the tests. Availability of an actual range with range scrap material, trained range staff, and complete stakeholder and regulator buy-in each contributed to the selection of this site for the TFF demonstration.

3.3 Test Site/Facility History/Characteristics

Eglin AFB is a fully functional Air Force Base with an active test range that creates potentially explosive contaminated range scrap. The range scrap operations at Eglin AFB are partially handled under contract by BAE Systems with disposal of live munitions performed by active UXO personnel assigned to the base. Other than siting the TFF, no special site preparation activities were required. The site, Field 5, see Figure 8 and Figure 9, had a non-operational runway which eliminated any grading or other surface requirements.

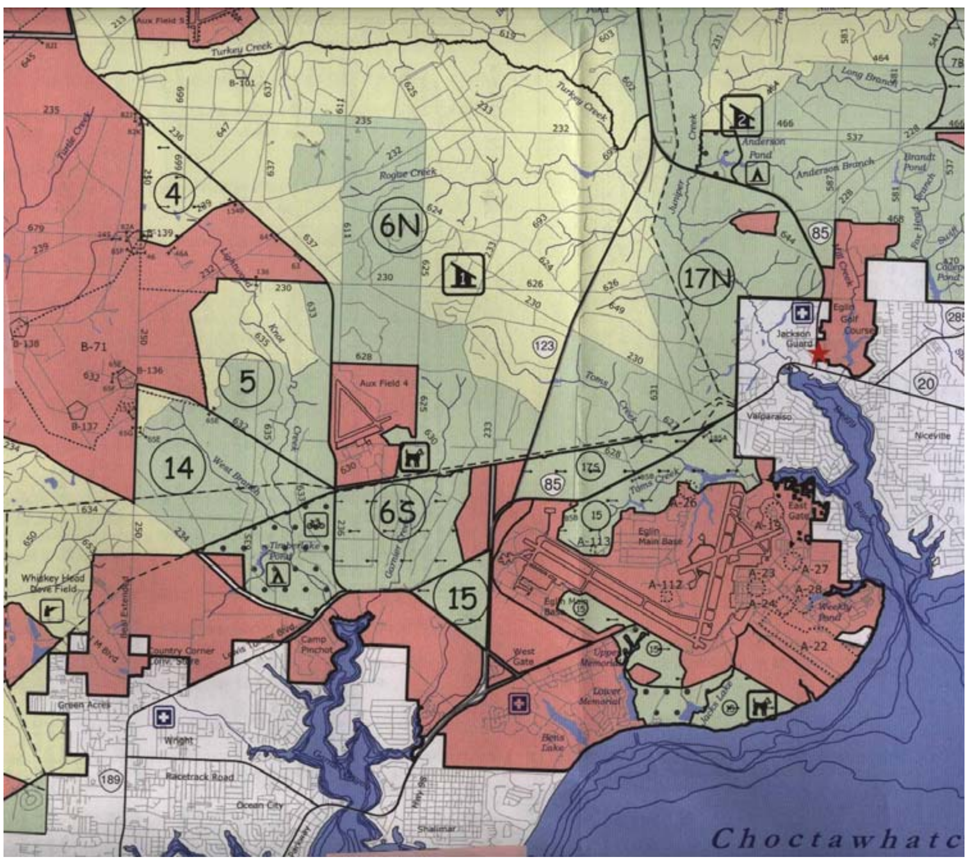

Figure 8: Map of Eglin Air Force Base. These tests were performed on Field 5.

Figure 9: Demonstration site is located on an old airfield at an active scrap staging area

3.4 Present Operations

The test site (Field 5) is an active staging area for the test materials needed. Reference Section 3.3.

3.5 Pre-Demonstration Testing and Analysis

No pre-demonstration testing and analysis was necessary.

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

Prior to actual testing, the following tasks were completed:

- Designed and fabricated and/or purchased at least 5 different trays/baskets configurations that can be used to hold the range scrap material.
- Procured instrumentation to measure and record load temperatures inside the furnace during the operational cycle of the TFF.

- Purchased Miscellaneous Equipment including scales, fuel meter, and handheld combustion analyzer.
- Developed the Test Procedures and Evaluation Plan for the program.
- A study was performed on EDE's Infrared camera to determine if it could effectively be used to monitor basket temperature. Due to the camera's limitations, it was not used for this demonstration, Reference Appendix A.3.
- Recalibration of the data acquisition system.
- Prepared Explosive coupons, see Section 4.2 and Appendix A.1 for more information regarding these coupons.

Minimal site preparation was needed for this project since the TFF was designed to be transportable. Once on-site, the TFF underwent a system check. The Data Acquisition System was tested and was working properly.

The TFF had its own power generator so the only consumables required were number 2 fuel oil and propane.

Approximately 15 tons of range scrap were processed, not including the target debris, throughout this demonstration:

- Phase 1: 12,500 pounds of range waste consisting of a mix of scrap which included 120 mm tank rounds, Special Fused Weapon (SFW) rounds, and steel and brass cartridge cases.
- Phase 2: 15,000 pounds of material in each density group was used. Debris from the test range was separated by parameters such as size, shape, and material composition. The debris was then mixed into piles with three separate density groups: high, medium, and low, reference Section 4.3. In addition, two loads of "Target Debris", two one-ton tank turrets and one three-ton tank gun, were selected for testing.
- Phase 3: used previously-processed range scrap.

There were a few unforeseen problems during the demonstration. Prior to testing, Hurricane Ivan blew through Eglin Air Force Base, and caused minor damage to the furnace. EDE corrected all visible damage prior to beginning testing. However, minor hurricane damage was observed periodically from time to time during testing causing minor delays. For instance, a failed spring caused the burner on the left to produce a much smaller flame than the one on the right. The burner was replaced and normal operations ensued.

Initial Phase 1 testing was done on 120 mm tank rounds. The amount of aluminum which melted during the heat soak was unexpected. Upon testing the first few loads in Phase 1, it was apparent that the baskets could not adequately contain the molten aluminum. The molten aluminum slightly warped the frame of the carbottom. This was

repaired prior to additional testing. The baskets needed to be modified in order to adequately contain this molten metal. Reference Section 4.3.1 for further discussion of this problem.

3.6.2 Period of Operation

Dates and Duration of each phase of the demonstration:

Phase 1: November 18-20, 2004; January 12-14, 2005
Phase 2: June 8-10, 2005
Phase 3: June 13-16, 2005

3.6.3 Area Characterized or Remediated

This is inapplicable to this demonstration.

3.6.4 Residuals Handling

This demonstration did not deal with the costs associated with transportation of scrap materials offsite. It is noted that once the materials have been classified as 5X, they are free to be used as scrap metal for direct sale to metal salvagers.

3.6.5 Operating Parameters for the Technology

The following operating parameters were determined based on this demonstration, see Section 4.2 for discussion:

- Basket Type – Basket CC1 was determined suitable for use with loads of varying densities and materials. This basket is structurally able to withstand the heat cycle, capable of containing all molten aluminum; and allows for effective heat transfer.

- Basket Weight and Location- Two baskets, each filled with 2500 lbs range scrap, should be placed on the carbottom and flashed in the same heat cycle. For lower density items, the baskets should be filled to maximum capacity.

- Total Labor Requirements. The TFF is designed to allow simple, all-inclusive control for one operator. A skilled forklift operator is necessary to efficiently load and unload the furnace. One of these operators should be either EOD certified of a civilian UXO technician. It is their responsibility to ensure that nothing is flashed that has any confined explosives and that all material is classified as 3X. As such, it is visibly clean. In order to maximize throughput, two additional laborers should be used to ensure that baskets remain filled and prepare material for offsite transportation.

- Reliable Process Cycle Times which will ensure that all material is decontaminated to 5X condition:

  1. Load/Unload Time- 8 min
  2. Purge Cycle- 2 min
  3. Heat Time- 40 min
  4. Soak-10 min
  5. Cool Time- 5 min (mean)

  With this process time, maximum throughput should be equivalent to 6-7 loads per 8-hour day (30,000- 35,000 lb/day); seven loads would be the expected norm. This allows for minor maintenance activities, lunch, and breaks.

- Fuel Requirements:

  #2 Fuel Oil - 11.8 gal/ton (27.2 gal/hr)
  Propane – 1 tank/ 20 tons

3.6.6 Demobilization

At the conclusion of the demonstration, minimal demobilization was required due to the fact that Field 5 currently acts as a fully operational staging area for range scrap. All range scrap used in this program was 5X and could then be sent offsite. The TFF and all ancillary equipment were transported back to the original operation site at Eglin AFB. Other testing equipment was shipped back to EDE in SLC, UT. There was no lasting impact to the site from this demonstration.

3.7 Selection of Analytical/ testing Methods

5X condition (650^{o}F for 10 minute soak) was demonstrated by measuring the temperature of each basket during each test. A set of thermocouples was placed throughout the basket's contents. Each test was considered complete when the furnace temperature cooled to 600^{o}F. It is noted that initially, it was planned to use an infrared camera to monitor the loads during cool down to verify uniformity of basket temperature. However, EDE determined that this would be ineffective due to the camera's limitations, reference Appendix A.3. The loads were removed and allowed to cool overnight. Stack emission measurements of CO, CO_2, NO_x, and O_2 were collected during each run using a handheld emission monitor. Procedures were developed by EDE for this demonstration.

3.7.1 Phase 1 Procedures

The procedural outline of Phase 1 was as follows:

1. Weigh empty basket.
2. Load Baskets with 2500 lbs of range scrap and re-weigh baskets.
3. Place 4 thermocouples in the locations specified in Figure 25 in Section 4.3.1.
4. Basket/tray will be loaded onto the carbottom of the TFF at position A or B, see Figure 10.

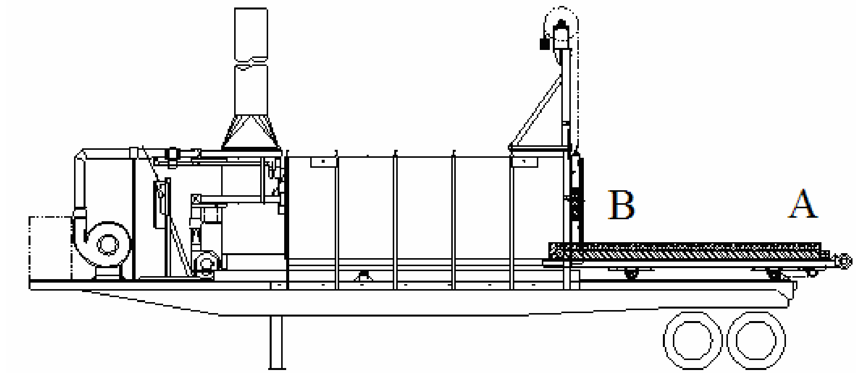

Figure 10: Position A is located by the door and B by the burners

5. Retract Carbottom into the TFF and close the door.
6. Record fuel meter reading.
7. Start purge cycle.
8. Start burners.
9. Test stack emissions.
10. Once each thermocouple (TC) has reached 650°F, hold for 10 minutes.
11. At 650°F (minimum) with all 4 thermocouples, batch held for additional 10 minutes.
12. After 10 minute soak time, turn both burners off and start the cooling fan.
    (It is noted that halfway through Phase 1 testing, it was proven that if the burners were turned off during the soak, the temperature inside the furnace was significant enough to hold the batch above 650°F for 10 minutes. For Phases 2 and 3, all tests were conducted with the burners off during the soak.)
13. Open the door when the temperature of the furnace reaches 600°F.
14. Record fuel meter reading.
15. Remove heated load from TFF and load the next basket/tray of material on the carbottom.
16. Allow all loads to cool overnight.

The following information was recorded for each test:

- Basket Identification type
- Basket location on carbottom
- Basket weights: empty, full, net weight of range scrap
- Time for each TC to reach 650°F

- Temperature of each TC at start of Soak
- Temperature of each TC at the end of 10 min Soak
- Temperature of each TC at time of Door Open
- Quantity of #2 fuel oil used
- O_2, CO_2, CO, and NO_x emissions during testing
- The baskets were evaluated based on their abilities to maintain structural integrity, contain molten aluminum, and allow effective heat transfer

All times and temperatures were monitored with the Eurotherm Recorder. For complete Eurotherm Test Data, see Appendix B.

3.7.2 Phase 2 Procedures

Phase 2 evaluated the effect of load bulk density on temperature profile for each heating cycle. Debris from the test range were collected and segregated into three separate density groups: high, medium, and low: Three loads of each density configuration were run.

Two baskets (2500 pounds net scrap or max volumetric capacity of the baskets for low density scrap) were prepared of each density type. The same basic procedural outline was followed and the same information recorded with the following exceptions:

1. Recording basket location and type was unnecessary, as baskets were placed in both the front and the rear of the carbottom.
2. Basket CC1 was selected based on Phase 1 results and used for all subsequent testing.
3. Rather than placing 4 thermocouples in each basket, 2 thermocouples were buried in the load in opposite locations, and 1 was placed on the floor of the carbottom to correlate stack temperature with chamber temperature.
4. Two explosive treated coupons were placed in each basket. Upon completion of the flashing cycle, the coupons were sent to a lab and analyzed to verify that they were completely free from explosive material.
5. The following items were recorded in addition to the items recorded in Phase 1:
    a. Labor times to:
        i. Time to place and remove thermocouples from baskets
        ii. Load and unload baskets on and off the carbottom

3.7.3 Phase 3 Procedures

The TFF was operated sufficiently to determine a reliable heat-up time which ensured that all material reached the required temperatures. As no parameters were changed from Phases 2 to 3, this was considered an extension of the previous phase. This phase

provided the information necessary to determine accurate throughput rates, fuel consumption, and labor rates to establish cost and performance data for TFF operations.

3.8 Selection of Analytical Testing Laboratory

The preparation and analysis of all explosive test coupons was handled by DataChem Laboratories, Inc located in Salt Lake City, Utah. This included the sample preparation/cleaning and spiking. For description of test coupon and results, see Section 4.1.3 and Appendix A.1. DataChem is an established and respected chemical laboratory founded in 1971 and is certified for SW-846 8330 which is the approved test method for explosives. DataChem also has the following certifications for the state of Florida:

- U.S. Army Corps of Engineers
- Department of the Navy
- American Industrial Hygiene Association (AIHA)
- Environmental Protection Agency (EPA)
- Air Force Center for Environmental Excellence (AFCEE)
- Department of Energy (DOE)

4 PERFORMANCE ASSESSMENT

4.1 Performance Criteria

Table 8: Performance Criteria

Performance Criteria	Description	Primary or Secondary
Phase 1		
Ability to 5X Range Scrap Material	Verify the ability of the TFF to effectively flash range scrap material.	Primary
Ability to handle wide variety of shapes and sizes	As range scrap varies in size from very small to very large and shapes include old munitions, metal plates, concrete slabs, the TFF must demonstrate its versatility to handle wide variety of shapes and sizes.	Primary
Basket Structural Integrity	The basket must be able to withstand temperatures up to 1400^{o}F. It must prevent warping and be able to withstand the rigors of loading / unloading.	Primary
Basket Molten Metal Catch	The basket must be able to contain any molten materials created during the flashing cycle.	Primary
Basket Heat-up Time	Time it takes each thermocouple in the basket to reach 650^{o}F.	Secondary
Basket Fuel Consumption	Amount of fuel used in each test.	Secondary
Basket Design Cost	Basket Costs were monitored and were factored into basket selection.	Secondary
Stack Emissions Levels	The following emissions were monitored: O_2, CO_2, CO, and NO_x to verify that air emissions will not have an impact on siting the TFF based on environmental restrictions.	Primary

Phase 2		
Labor Requirements to Maximize Throughput	The amount and type of labor was determined by observance of process times. Recommended labor rates maximized throughput rates.	Primary
Monitor Heat-up time required for loads of various densities	Mean heat-up time was determined with the following density loads: High, medium, and low. They were compared to determine how to maximize throughput.	Primary
Explosive Coupons	Explosive treated coupons were placed in a basket. Following the flashing cycle, they were analyzed at a lab to determine if all explosive residue was removed.	Primary
Phase 3		
Fuel Consumption	The fuel consumption was monitored to determine accurate throughput rates and overall costs	Primary
Monitor Cycle times required for TFF operations to develop realistic throughput rates	Instrumentation and process times were monitored.	Primary

4.2 Performance Confirmation Methods

This project demonstrated that range scrap and target debris could be thermally decontaminated to a 5X level in the TFF. The thermocouples were monitored with the Eurotherm Data recorder. Initially, the data recorder was set to take several samples per minute. After November testing, it became apparent that this data volume was too bulky and offered no advantage. A sampling frequency of 1 sample per minute was used for the rest of the demonstration. Complete test data is located in Appendix B. Obtaining the data was simple and usable data was obtained for each test.

In addition to monitoring the thermocouples, each basket was weighed with a scale. These weights were recorded and

In summary, the following major items were recorded for each test:

- Heat time
- Cooling Time
- Fuel usage
- Thermocouple data
- Weight of the scrap material

Weights were recorded by a scale prior to each test. Most loads were filled to 2500 lb scrap material. Items with lower density, such as SFW's, were filled to volumetric capacity. Labor, instrumentation, and other necessary times were monitored periodically throughout testing. These times did not vary much from test to test. Therefore, it was unnecessary to monitor explicitly for each individual test. For a complete explanation of all recorded data for each phase, see Section 3.7 and Appendix B.

Most of the data collected was simple and straight forward to both obtain and analyze. Interference that would hamper and/or interfere with data collection did not occur. Substantial redundants were included so that usable data for all test runs occurred.

Preparation of Test Coupons

The major preparation and analysis issues dealt with the explosive test coupons used in Phase 2. The test coupons were commercially-available washers made of 304 stainless steel. The outside diameter was approximately one-inch, the inside diameter was ¼ inch and each washer was approximately 1/16 of an inch in thickness. These test coupons were supplied to DataChem to be spiked with the explosives. Each test coupon was first cleaned at the DataChem facility to remove any trace contamination and oils. Each sample coupon was then spiked with a mixture of explosives. DataChem has suggested that the actual explosive calibration test solution approved for EPA method 8330 be used to spike the test coupons. This calibration test solution contains the following explosives and explosive by products that were analyzed by test method 8330.

8330 - Explosives

1,3-Dinitrobenzene
1,3,5-Trinitrobenzene
2-Amino-4,6-Dinitrotoluene
2-Nitrotoluene
2,4-Dinitrotoluene
2,4,6-Trinitrotoluene
2,6-Dinitrotoluene
3-Nitrotoluene
4-Amino-2,6-Dinitrotoluene
4-Nitrotoluene
HMX
Nitrobenzene
RDX
Tetryl

In October 2002, Parsons issued a report titled "Report on Process Verification and Quality Control for the Kaho'olawe Car Bottom Thermal Processing Unit for Scrap Material Processing." This report outlined the testing that was conducted on a nearly identical TFF that was then located in Hawaii. This testing also used explosive spiked coupons. The test results on the coupons were below detection limits on all explosives except for HMX which was measured on one of the samples. HMX is therefore anticipated to be the explosive constituent of primary concern.

After the preparation or spiking of sample coupons by DataChem, each spiked sample was then placed into a separate, sterile, 47 mm polystyrene petri dish supplied with a closeable lid. In addition an unspiked, clean test coupon was prepared as a trip blank. At the end of the testing, the trip blank and also one of the untested, spiked coupons were returned to DataChem for analysis as part of the Quality Assurance program.

Sample Handling

In order to minimize potential cross-contamination or other potential variables, the placement, handling and recovery of all test coupons both before and after treatment was done by a single person, the test engineer. Whenever handling the test coupons, sterile, disposable gloves were used.

Chain of Custody

A Chain of Custody form was filled out by the test engineer and included in the shipping container back to DataChem. A copy of this Chain of Custody is attached, see Appendix A.1.

Sample Recovery

In the referenced October 2002 report by Parsons, it was determined that adequate amount of solvent was needed to completely recover the explosive residue from the coupon. The size of coupon used in this test series was small enough so that it was actually submerged in the solvent in order to ensure complete recovery of any potential sample.

Table 9 Summary of Explosive Test Coupons Performance Data

Decontamination of Range Material using Transportable Flashing Furnace El Dorado Engineering	
Types of Samples Collected	Explosive-treated Coupons
Sample Frequency and Protocol	5 coupons per 5000 lb treated scrap
Quantity of Material Treated	50 304-SS washers
Untreated and treated contaminant concentrations	50 coupons per 25 tons untreated range scrap
Cleanup objectives	All 50 coupons explosive Non Detect
Comparison with Clean-up objectives	Clean-up objectives were all met
Method of Analyses	EPA Test Method 8330

Table 10: Expected Performance and Performance Confirmation Methods

Performance Criteria	Expected Performance Metric (Pre-demo)	Performance Confirmation Methods	Actual (post-demo)
Primary Criteria (Performance Objectives)			
Ability to 5X range scrap material	Yes	>650^{o}F for 10 min	Yes
Ability to handle wide variety of shapes and sizes	Yes	>650^{o}F for 10 min	Yes
Basket structural integrity	Yes	Operator acceptance	Yes for CC1
Basket can contain molten material	Yes	Operator acceptance	Yes for CC1
Labor requirements to maximize throughput	Determining an appropriate heat cycle and process times, labor rates can be estimated.	Total Process Times (min)	Total Process Time is 65 minutes. Therefore, to maximize throughput, 7 tests should be run a day. To accomplish this, 2 operators and 2 laborers are needed
Explosive Test Coupons	Verify that the flashing cycle will eliminate all explosive material.	Laboratory analysis of 50 test coupons.	Explosive Non-Detect on all test coupons
Stack Emissions Levels	Below de minimis levels:	CO< 10 lb per day NO_x<10 lb per day	Averages at 7 tests/ day throughput rate: CO = 0.58 lb / day NO_x = 1.84 lb/ day
Explosive Coupons	ND	Laboratory analyzed	ND for All
Operating Parameters			
Heat Time	Determine the heat time to ensure that the material is flashed.	>650^{o}F (min)	40 min
Fuel Consumption per Process Time	Determine fuel consumption per process time	Fuel Consumption (gal per hour)	27.2 gal per hour
Cycle time	The total process time per test was determined.	Total Process time (min)	65 min

4.2.1 Additional Guidelines for Detection/ Discrimination Technologies Demonstrating at Standardized Test Sites

This section is not applicable to this demonstration.

4.3 Data Analysis, Interpretation, and Evaluation

4.3.1 Phase 1

This demonstration project was divided into three phases. The primary objective of Phase 1 was to verify that range material could be flashed effectively with the TFF. In order for material to be flashed, each load was heated until the material reached 650°F. This temperature was monitored with 4 thermocouples per basket. This data was recorded with the Eurotherm data recorder. It was easily observed that this material could be effectively flashed, see Figure 11. 120 mm tank rounds were used for this test.

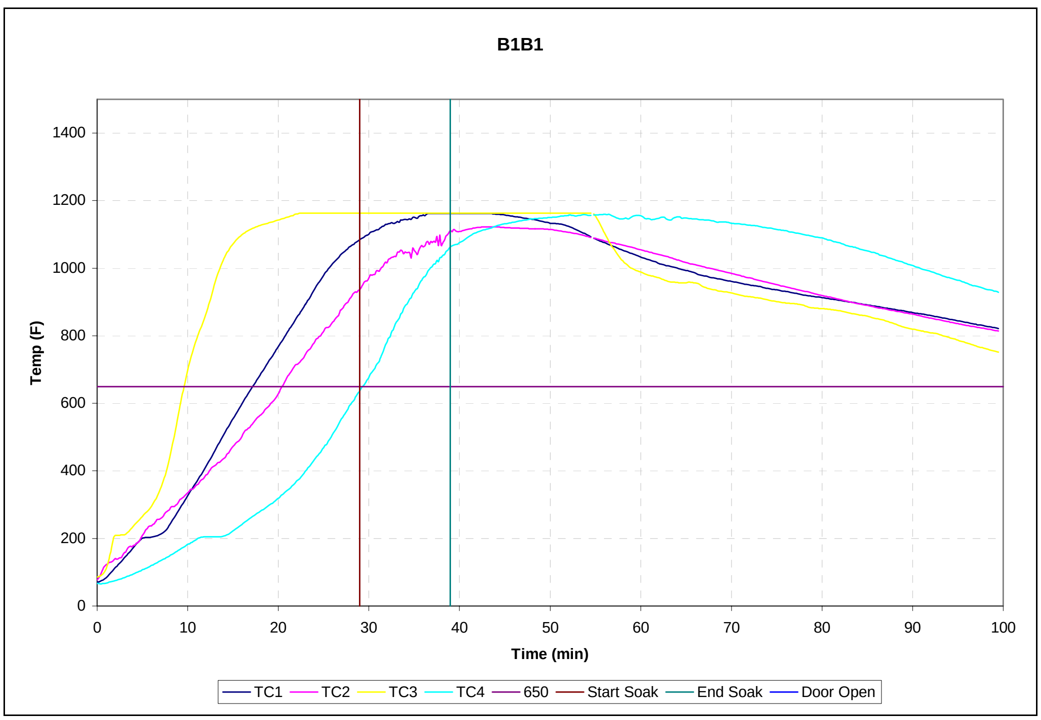

Figure 11: Initial Phase 1 test showing that the TFF can effectively heat scrap to 650°F and hold it for 10 minutes.

Note that the thermocouples heat to 650°F at varying rates due to their location inside the basket. When the final thermocouple reached 650°F, the heat-up time was complete (29 min) and the 10 minute soak is started. By the end of the soak, the material was 1100°F, almost double the required 650°F limit.

Another primary objective of Phase 1 was to evaluate different basket designs as they related to the flashing cycle. These baskets ranged in size from 200-3000 lb. Some were specifically designed and fabricated to reduce structural wear while others were less-expensive, commercially available, semi-disposable baskets.

All fabricated containers were designed by EDE and fabricated at Complex Fabricators, Inc, located in Salt Lake City, UT.

Fabricated Container– R1

This container has a solid pan bottom to catch ash or molten material fabricated from ¼” thick low carbon steel. Side supports are ½” x 3” bar around the perimeter with bolted connections to maximize thermal resistance. The basket is bolted to a support structure to allow handling with forklift. This basket is able to hold 2500 lb of scrap or maximum volume of 42 ft^3.

Figure 12: Fabricated Basket R1

Fabricated Container - C1

This container has a solid bottom to catch ash or molten material and fabricated from 3/8” thick low carbon steel. Sides consist of 3/8” x 4” rails with approximate 2” gap. Tray is elevated 24” to allow for better air movement. The basket is able to hold 2500 lb of scrap or maximum volume of 61 ft^3.

Figure 13: Fabricated Basket C1

Fabricate Container - B1

This container has a solid bottom to catch ash or molten material and fabricated primarily from 3” x 3” angle for strength and durability. This basket has an all-bolted design to minimize thermal distortion. It also has a gated end to facilitate dumping the decontaminated load. The basket is able to hold 2500 lb of scrap or maximum volume of 59 ft^3.

Figure 14: Fabricated Basket B1

In addition to the fabricated baskets, two inexpensive, commercially-available, semi-disposable baskets were purchased from Global Industrial. They could be used as many times as possible until they showed major signs of wear. It is noted that these baskets were never expected to be acceptable for all range scrap items, but could possibly be used

to provide a practical, low-cost alternative for a significant portion of the items to be treated.

Basket J1: Folding Wire Container

This basket is a commercially available, low-cost option. It has a solid bottom to catch ash or molten material and 2x2 #2 wire mesh sides to allow for better air movement to speed up heat transfer. The baskets collapse for easy storage but can also be stacked up to four high. This would allow for easy loading. They also have a drop down gate to allow loading of smaller items even when they are stacked. Each basket is able to hold up to 4,000 lb or maximum volume of 41 ft^3. It only weighs 194 lb and costs approximately $200.

Figure 15: Folding Wire Basket J1

Basket J2 - Stackable Steel Container

This container has a solid bottom to catch ash or molten material and 3/16” thick 2” angle corners. It has 3/16” wire mesh sides to allow for better air movement to speed up heat transfer. These containers can be stacked up to five high. Each basket is able to hold up to 2,500 lb or maximum volume of 18 ft^3. It only weighs 145 lb and cost is similar to Basket J2.

Figure 16: Stackable Steel Basket J2

Each basket was evaluated according to the following criterion:

- Ability to maintain structural integrity
- Ease of heat transfer
- Ability to contain the molten metal.

While testing the previous five baskets, it became apparent that for this particular scrap pile, there was a significant amount of molten aluminum. While it was expected that some aluminum would be present, the quantity of actual molten aluminum produced was significantly more than expected. Each of the baskets mentioned did not have adequate capability of containing all of the molten aluminum. This molten aluminum went onto the carbottom, see Figure 17, creating some minor problems. The frame of the carbottom warped slightly. This was repaired prior to additional testing.

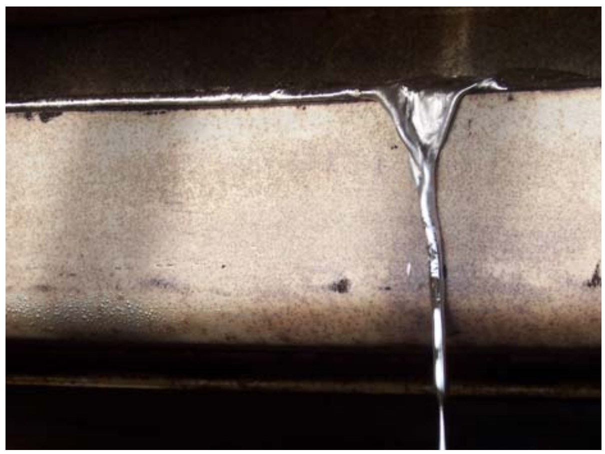

Figure 17: Molten Aluminum overflowing on the sides of the carbottom

From these initial five baskets, important observations were made. After initial testing, two of the three fabricated baskets, R1 and B1 did not show any visible signs of deformation, see Figure 18. The bolts helped the basket to maintain structural integrity.

Figure 18: Baskets R1 and B1 respectively show no visible signs of deformation after initial testing.

Conversely, Basket C1 and the commercially-available, inexpensive basket J2 did not fare so well, see Figure 19.

Figure 19: Baskets C1 and J2 have warped after initial testing.

The unsupported steel and wire mesh do not adequately withstand the heat load. Taking into account the lessons learned from the previously tested baskets, EDE designed two new baskets that would maintain their structural integrity and be able to prevent the molten aluminum from getting on the carbottom.

Basket RC1

This container's basic design was taken from Basket R1. It is open which freely allows convective heat transfer to the contents of the basket. This container has a removable catch tray to catch ash and a significant amount of molten material. This basket has an all-bolted design to minimize thermal distortion. The basket is able to hold 2500 lb of scrap or maximum volume of nearly 21 ft^3.

Figure 20: Fabricated Basket RC1

Basket CC1

This container also was designed for durability and ability to catch a significant amount of molten material created during the flashing process. It was taken from the design of both C1 and B1. This container has a removable catch tray designed to catch a significant amount of molten material. As with some of the other baskets, this basket has an all-bolted design to minimize thermal distortion. It also has a gated end to facilitate dumping the decontaminated load. The basket is able to hold 2500 lb of scrap or maximum volume of nearly 42 ft^3.

Figure 21: Fabricated Basket CC1

Baskets RC1 and CC1 were compared and and their performance analyzed.

Figure 22: Basket RC1 loaded with 120 mm shown with associated catch basin

Figure 23: Basket CC1 immediately following a test. Note the molten material which has collected in the catch basin. Off to the right, a large aluminum ingot from a subsequent test.

In the center of these baskets, there are holes which allow this molten material to go into the bottom trays. In 2 of the test runs with Basket RC1, some of these holes clogged. This made it difficult to remove the material from the basket after cooling. In addition RC1 showed slightly more signs of warping after initial tests. It was estimated that Basket CC1 would last longer in an extended run of range scrap.

Table 11: Comparison of Baskets RC1, CC1

	Basket RC1	Basket CC1
Average Heat Time (min)	25	32
Structural Integrity	Small amount of warping	No visible deformation
Catch Basin Capability	Adequate	Adequate
Volumetric Capacity (ft^3)	20.8	41.7
Ease of Load and Unload	Low center of gravity makes it difficult to unload. In addition, aluminum solidified in the holes which made it even more difficult to unload	High center of gravity makes it easy to unload.

Basket RC1 was evaluated and its advantages included a slightly shorter heat-up time. However, this is offset by the significant reduction of volumetric capacity. For less dense items, such as SFW's, the scrap load would be substantially reduced due to its volumetric constraint.

Basket CC1 was significantly easier to unload; its center of gravity is higher and therefore easier to tip; the forklift simply needed to push it on its side and easily tipped, whereas for RC1 the center of gravity is much lower and therefore harder to tip, see Figure 24.

Figure 24: Unloading Basket CC1 compared to Basket RC1

Basket CC1 was selected for range scrap flashing use. It is important to note that the baskets are going to be under severe loading and heat. The life expectancy of a basket is estimated to be one basket for every 1250 tons processed in it. However, actual basket life can only be determined with extended use.

In addition to evaluating the baskets, the TFF was tested to see if material with various sizes and shapes of range scrap. During January Phase 1testing, 120 mm munitions, 155 mm shells and BLU 97 were successfully flashed, see Figure 25 (respectively).

Figure 25: Material flashed in Phase 1 testing

With the initial 5 baskets tested in November, effects on vertical location, location on the carbottom, and the amount of baskets per test were going to be analyzed. For position of the thermocouples, see
Figure 26.

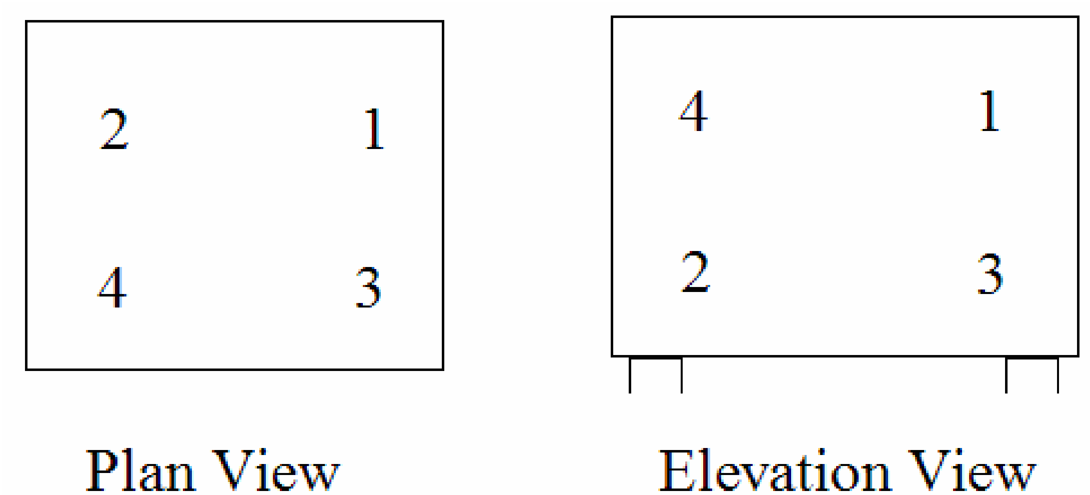

Figure 26: Phase 1 Placement of the Thermocouples in the basket

The time it took for each of the thermocouples to reach 650^{o}F was monitored. For Phase 1 testing, results are summarized in Table 12.

Table 12: Average Time in minutes in Phase 1 tests 1-10

TC1	TC2	TC3	TC4
14	23	28	18

Table 12 shows that the thermocouples located at a higher position in the basket (1 and 4) heated faster than the thermocouples towards the bottom. This was taken into account with the basket design. Basket CC1 is set so as to place the material as high as possible without damaging the ceramic wool insulation.

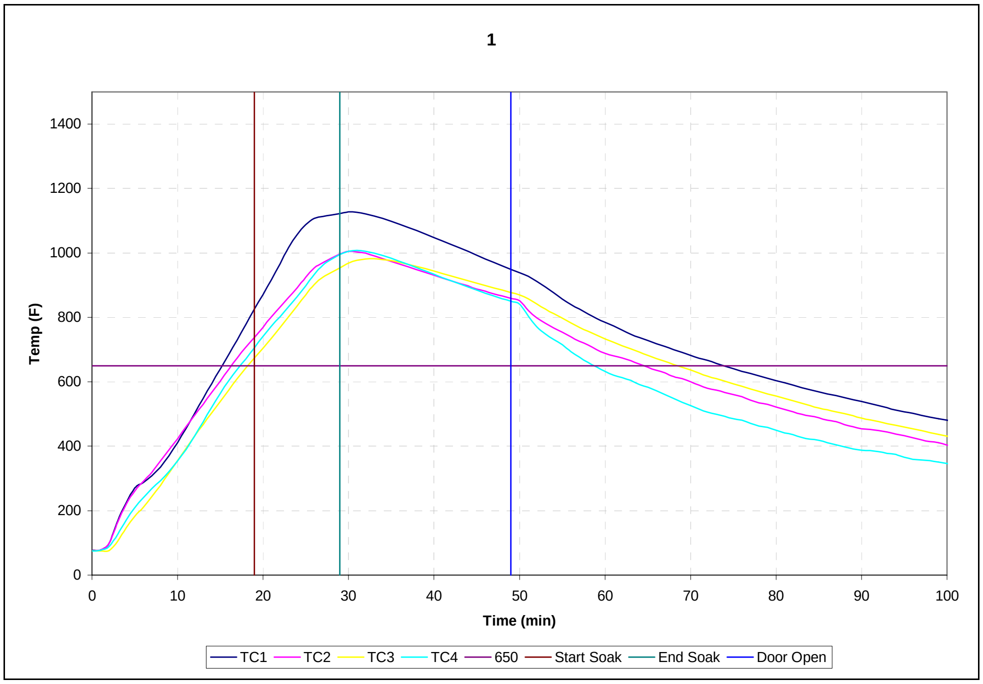

Figure 27: 120 mm shells-position A- Burners on during soak

Another significant discovery was made. Figure 27 shows Test 1, Jan 12, 2005. Note that by the time the soak was completed, the temperature of the thermocouples had climbed to more than 900°F. It was hypothesized by EDE test engineers, that during the soak, the temperature inside the TFF would keep the temperature above 650°F without the burners on. If so, the TFF would use significantly less fuel and reduce the cooling time significantly thus reducing overall fuel costs and increasing throughput.

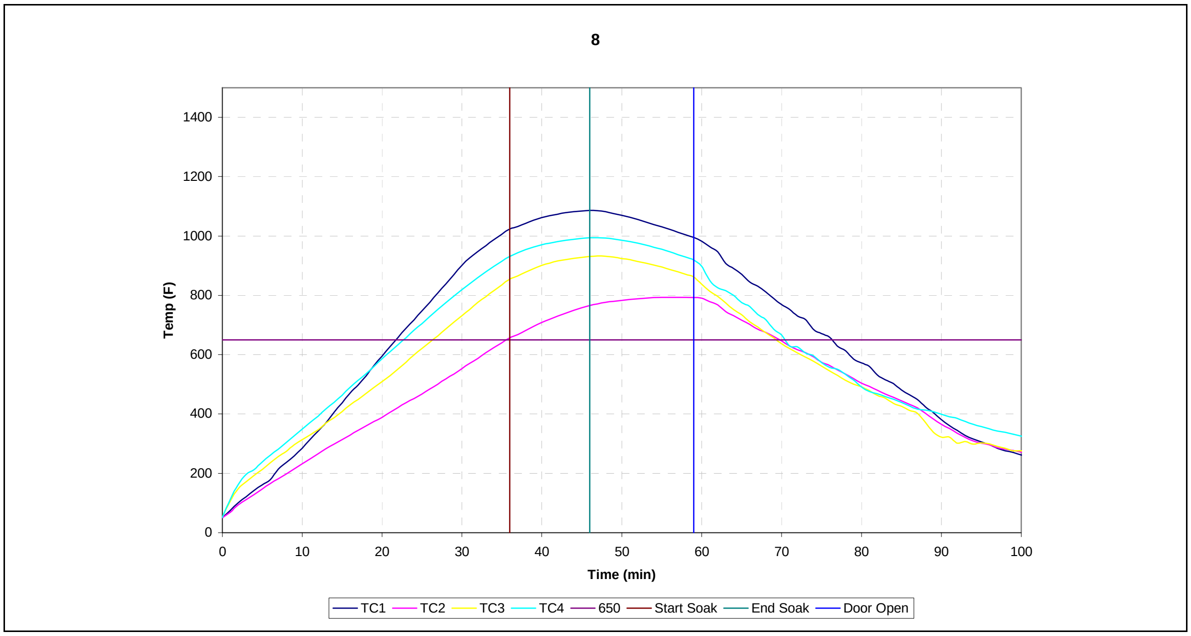

Figure 28: 120 mm shells-position A- Burners off during soak

Figure 28 shows a significant reduction in the slope of the curve following the start of the soak. Also, there is a significant reduction of cooling time, 20 minutes in test 1 to 13 minutes in test 8. The temperature of the basket still remained above the required 650^{o}F limit. Generally, this was observed throughout remaining testing.

Summary Phase 1

Each objective of Phase 1 was met and summarized in Table 13:

Table 13: Objectives / Results Summary Test Series 1

Verify that Range Scrap Material can be effectively classified from 3X to 5X	Test results clearly show that range scrap material can be effectively flashed and classified as 5X.
Verify that a wide variety of shapes and sizes of range scrap can be effectively classified from 3X to 5X	Throughout Phase 1, the following munitions were tested, 120 mm shells, BLU 97, and 155 mm shells. Each was able to be effectively flashed.
Determine an effective Basket/ Tray design	Basket CC1 was selected due to its structural integrity, ability to contain molten materials, and it allows effective heat transfer.
Test the impact of tray location and basket vertical position in the TFF	Reduced heating times were observed with material that is higher off of the floor and closest to the flame. This was taken into account in the design of Basket CC1 which was selected for further tests throughout this demonstration

4.3.2 Phase 2

Phase 2 loads were segregated by three separate densities: high; medium; and low. Each load included 2 baskets of each material. High Density loads included thick steel plate, concrete slabs, and other range material. Medium density loads included 155 mm shells. Low density loads included SFW mechanisms.

Figure 29: High, medium, and low density loads

The baskets were loaded with 2500 lb of range scrap or maximum volumetric capacity for the low-density loads. Each basket was instrumented with 2 thermocouples, with an additional thermocouple placed on the floor of the carbottom, see Figure 30. The thermocouples were placed near the bottom because material at the bottom of the baskets was found to heat slowest in Phase 1.

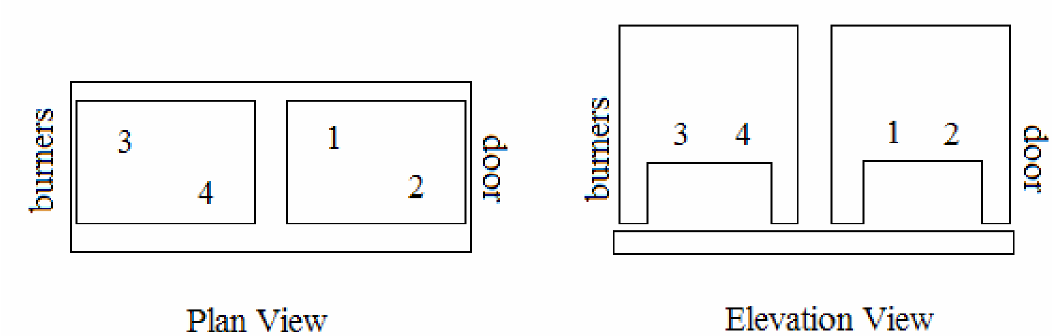

Figure 30: Thermocouple placement in Phases 2 and 3 testing

It is noted in the referenced October 2002 Parsons report that Kaho'olawe noticed that the baskets closest to the door heat faster than baskets closest to the burners. This was not the case for this demonstration. Table 14 shows that baskets closest to the burners, on average, heated 32% faster than baskets by the door. EDE believes that this difference is caused by the improved basket design used in this demonstration.

Table 14: Phase 2 and 3 Results by location on the carbottom

Basket Position	By Door	By Burner
Average Heat Time (min)	26.4	17.9
Standard Deviation (min)	5.9	4.6

The basket by the door takes the longest to heat to 650^{o}F. Inside this basket, TC2 took longest to heat 11 out of the 14 range scrap test runs in Phases 2 and 3. The material located in the bottom of the basket nearest to the door will be the last of the material to be decontaminated. With the process times discussed in Section 2.3.2, this material will be soaked at 650^{o}F for 10 minutes.

Phase 2 loads were tested to determine if bulk load density had any significant effect on the correlating process parameters heat-up time and fuel consumption, see Table 15.

Table 15: Bulk load density has minimal effect on the heat-up time and fuel usage

Densities (# runs)	Mean Heat-up time (min)	Mean Fuel Usage (gal)
Low	24.3	17.3
Medium	29.3	22.0
High	27.7	20.3

There was no noticeable effect caused by loads with differing densities. This is further evidence that instrumenting loads is unnecessary, see Section 4.3.3.

Another primary testing objective involved treated explosive coupons made up of 304-Stainless Steel washers. These coupons were treated or spiked with explosive materials at DataChem Laboratories; see Section 3.8 for laboratory information. Two coupons were placed in each basket and an additional one on the floor of the carbottom, a total of five coupons per load during Phase 2. Special care was taken by test engineers when placing and removing the coupons to avoid any contamination, see Section 3.8. Each coupon was placed in a box typically used by electricians, see Figure 31. A thermocouple was located in each box to monitor temperature. The metal boxes were used to protect the coupons from coming in contact with molten metals. Also it helped with locating the coupons following each test. The box was capped and placed inside the baskets. At the conclusion of each test run, the coupons were individually placed in clean, sterile containers, labeled, sealed, and then shipped to the laboratory for analysis.

Figure 31: Explosive Coupon Ready to be placed in the basket

See Appendix A.1 for complete Analytical Report from DataChem Laboratories. This report lists all test results plus the Quality Control data performed by DataChem to validate the test data. Of primary importance, the test results from all test coupons were below detection limits for all explosives tested. Of primary interest was RDX and HMX; the test results were negative on all test coupons. The test results, including detection levels, plus the results on the spiked sample and the trip blank are summarized in Table 16.

Table 16: Summary of Test Coupon Results

Explosive	**Detection level (µg)**	**Spiked Sample (µg)**	**Trip Blank (µg)**	**All Test Coupons (µg)**
1,3,5-Trinitrobenzene	0.20	ND	ND	ND
1,3 -Dinitrobenzene	0.20	ND	ND	ND
2,4,6-Trinitrotoluene	0.40	ND	ND	ND
2,4-Dinitrotoluene	0.20	ND	ND	ND
2,6-Dinitrotoluene	0.40	ND	ND	ND
2-Amino-4,6-dinitrotoluene	0.40	3.21	ND	ND
2-Nitrotoluene	0.80	ND	ND	ND
3-Nitrotoluene	0.80	ND	ND	ND
4-Amino-2,6-Dinitrotoluene	0.40	3.01	ND	ND
4-Nitrotoluene	0.80	ND	ND	ND
HMX	0.40	4.08	ND	ND
Nitrobenzene	0.40	ND	ND	ND
RDX	0.40	2.58	ND	ND
Tetryl	0.40	1.75	ND	ND

ND = not detected or below the detection level

These results are vital in that this is additional proof that the TFF can be used to effectively flash range scrap, and provides additional confidence that the material is correctly classified as 5X.

Target Debris

Procedures were adjusted upon the start of Phase 2 to attempt to flash target debris. Target debris, generally, is larger than range scrap. At Eglin AFB, tanks and other large items are used as targets. When flashing these larger items, it is important to be aware of the size constraint of the TFF. The chamber is 5’ X 7’ X 17’.

Care needs to be taken to ensure that the target debris does not touch the ceramic wool insulation. This will be the cause of costly repairs. Two loads of target debris were selected for testing during Phase 3. Two 1-ton commander tank turrets were placed on the trays used for Basket CC1, see Figure 32.

Figure 32: Two Tank Commander Turrets Ready to be placed in the furnace

In addition, one three-ton gun was selected to be flashed. This gun was too big to be placed in the trays. It was placed on Basket R1, see Figure 33. It is noted that Basket R1 was not able to structurally withstand the load. Additional loading platforms will need to be designed and built to account for these items of larger size.

Figure 33: Three-ton tank gun, placed in Basket R1, ready to enter the TFF.

For the most part, the procedures did not need to be adjusted with exception of how to place the thermocouples to ensure that they would maintain contact on the gun's surface throughout the test. Tie wire was used to secure the thermocouples.

Also, it was important to note that for flashing range scrap material, the cooling blowers did not need to be on. Emissions were not affected. However, with some target debris, there are additional combustibles, such as oil, grease, etc. To provide additional oxygen for combustion, the cooling blower needed to be on during the heat cycle. See Section 4.3.3 for discussion for results of target debris tests.

Manpower

As was discussed in Section 2.3.3, the required manpower was monitored and the recommendations made in order to maximize throughput. Two operators are needed. One is primarily responsible for operation of the furnace and the other, a skilled forklift operator, responsible for loading/ unloading the carbottom. Two additional laborers should be utilized to load the baskets with the scrap. They should also be responsible for preparing previous loads for removal from the site and ensuring that fuel levels are maintained properly.

All test objectives were met by Phase 2 testing and are summarized in Table 17:

Table 17: Objectives/ Results Summary Phase 2

Verify that explosive material placed in the baskets will be eliminated with the TFF.	Each of the nine runs in Phase 2 included four explosive coupons in the baskets and one on the floor. In every case, lab results showed that all explosive residue was eliminated.
Monitor Heat-up time for loads of various densities.	The average heat-up time for loads of varying density was compared. Little variation was caused by differing densities.
Develop procedures to process target debris	Two target debris were selected for testing and procedures were adjusted in order to process these items.
Recommend labor requirements to maximize throughput	Recommended full time labor requirements are 2 skilled operators (includes a forklift operator) and 2 additional laborers.

4.3.3 <u>Phase 3</u>

Phase 3 was an extension of Phase 2. The primary objective was to define operating parameters which will maximize throughput and minimize overall cost. No procedural changes were made from Phase 2 with the exception that explosive coupons were not used.

Additional tests were required in order to determine an accurate set heat-up time. In addition to the scrap that was flashed in Phase 2, BLU 108s, 120 mm, and the target debris was flashed. At the same time, the operating parameters were determined to most efficiently maximize throughput and minimize overall cost.

As was discussed in Section 2.3.1, EDE had two hypotheses which would ensure that the material was sufficiently flashed:

- Instrumenting each load
- A Reliable Heat-up Time can be established that ensures that material reaches required temperature thresholds (no instrumentation needed)

Testing results showed that a set heat-up time can be established and assure that all material is decontaminated to 5X levels. Instrumentation times and costs were

determined. While instrumenting each load gave full confidence that the material was flashed, it introduced the following problems:

- EDE purchased 20 thermocouples at the beginning of testing. After running approximately 30 tests, only 13 worked properly at the end of the test. Assuming this failure rate throughout operation, an instrumentation cost of $30 per test needs to be added to cost estimates.
- Data Acquisition System cost is approximately $10,000 and includes a data recorder, thermocouple box, and a laptop computer. In addition, significant extra set up time, care, maintenance, and facilities are required. This data acquisition system would need to be integrated with current TFF design.
- Thermocouples get stuck in the baskets due to melted materials such as aluminum. Additional time would be needed sporadically for removing the thermocouples.

Table 18: Phase 2 and 3 Process Parameters

	Instrument Labor Time (min)	Heat Time (min)	Fuel Consumption (gal)
Instrumented	17.1	26.2	18.8
Worst-case Heat Soak	NA	38	28

The uninstrumented fuel consumption was 28 gallons. This corresponded to a heat-up time of 38 minutes. EDE recommends a heat-up time of 40 minutes which corresponds to a fuel consumption of 29.5 gallons per test. Estimated Cost of Instrumentation includes estimated thermocouple maintenance costs (based on the amount of thermocouples which failed during the demonstration – 7 broken thermocouples for 30 tests), and additional labor costs. The average instrumentation time per load (2 thermocouples per basket – 4 per load) is approximately 17 minutes, see Table 19. The average time saved in cook time is approximately 14 minutes with an instrumented load.

Table 19: Time for each load in minutes

	Instrumented Load (Mean)	Uninstrumented Load (Worst Case)
Load/ Unload Time	**10**	**8**
Purge Cycle	2	2
Cook Time	**26**	**40**
Soak Time	10	10
Cool	5	5
Instrumentation	**17**	**NA**
Total	70	65

Cost estimates in Table 20 are based on the estimated fuel cost of $2.20/gal.

Table 20: EDE initial major cost estimate for instrumented vs. uninstrumented load

	Cost Fuel	Instrumentation Maintenance	Labor Cost	Total Cost Comparison
Instrumented	$41.36	$29.17	$163.33	**$233.86**
Uninstrumented	$66.00	NA	$151.67	**$217.67**

It is noted that this cost estimate does not include the price of the data acquisition system. It is already clear that a reliable, unchanging heat scenario is more cost efficient. Instrumenting each load is unnecessary. Utilizing the set process times discussed in Section 2.3.2 are less expensive and it will eliminate the problems associated with instrumenting each load.

Total Process Time

With an uninstrumented load, and with the appropriate operating parameters discussed in Section 2.3, EDE determined a maximum range scrap throughput of 6-7 loads per day with 7 loads as the norm. This corresponds to 6.5 to 7.6 hours of process time each day. Running 5 days a week, 50 weeks a year, it is possible to decontaminate 3750 to 4375 tons of range scrap per year.

Target Debris

It is noted that these two loads of target debris were done as a favor to Eglin. The main purpose in this particular area of testing was to demonstrate that target debris could be handled by the TFF. While this demonstration did not focus on treating all types of target debris, clearly the TFF can handle these items.

Figure 34: Two commander tank turrets following thermal treatment.

Due to the significant heat exposure of the surfaces in this target debris, the time it takes to heat the initial surface to 650°F is minimal. In fact with the tank turrets, one of the thermocouples in the rear of the furnace did not stay above 650°F during the 10 minute soak, see Figure 35. In heating range scrap as opposed to target debris, the average time it took to heat a load to 650°F is 26 minutes. It only took 11 minutes with the turrets. The material did not have adequate time to absorb enough heat.

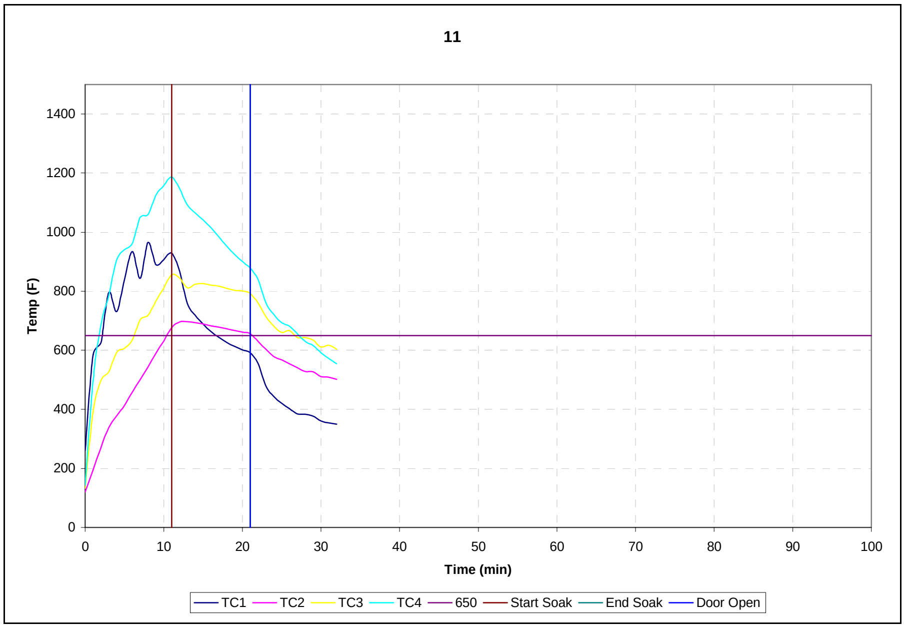

Figure 35: Tank Turret Test Data. TC1 did not stay above 650°F during soak.

With the gun, the temperature reached 650°F even faster than the turrets at 3 minutes. For this test, the burners were left on for 20 minutes, see Figure 36.

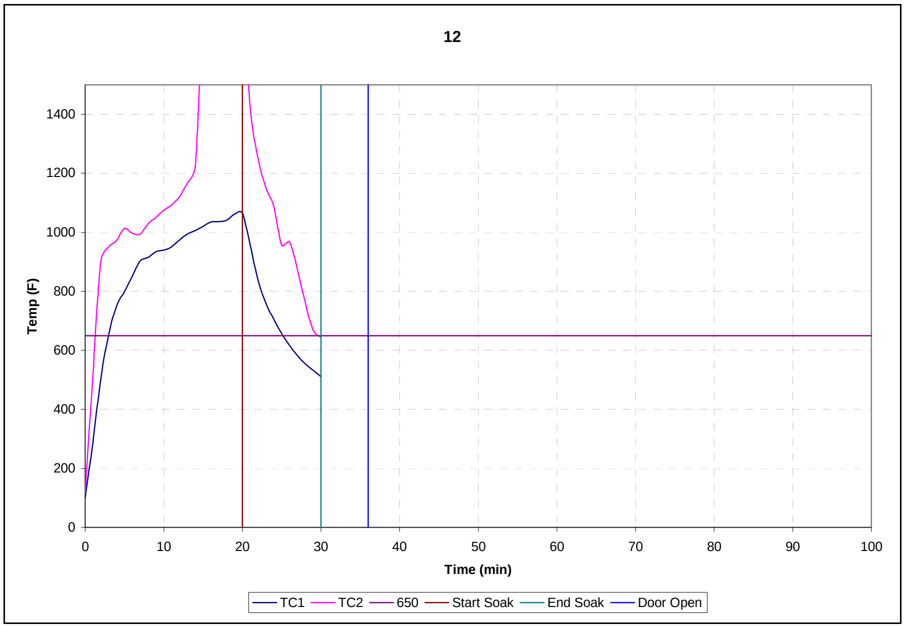

Figure 36: Three ton target debris flashed in the TFF

Figure 36 shows that one of the thermocouples lost contact with the surface of the target debris. Although the heat time to reach the 650°F limit is much less with this associated target debris compared to range scrap, target debris should be allowed to heat for the full

heat time discussed in Section 2.3.2. This will ensure that all of the cracks and crevices that can harbor any explosive residual will be heated sufficiently.

During these target debris tests, CO emissions were slightly more (still below de minimis limits) than with the other range scrap, see discussion in Section 4.3.4. This additional CO is due to additional combustibles such as oil, bearing grease, and other things located in the target debris. The combustion blower was on for these tests.

It is noted that a large target debris loading platform is necessary to hold target debris larger than 6 ft by 6 ft.

Table 21: Objectives/ Results Summary Phase 3

Define Throughput parameters for TFF	Throughput parameters are defined for TFF, see Section 2.3
Use the TFF to decontaminate to 5X two separate runs of target debris	Two 2000 lb tank turrets and a 6000 lb gun were flashed.
Determine whether it is more or less cost efficient to instrument loads	It is more expensive to instrument loads and produces additional problems that can be avoided if loads are flashed using the worst case scenario, 40 minute heat-up and 10 minute soak.

4.3.4 Emissions

With the TFF's that EDE has provided for flashing, no environmental permits were required. Most states have a threshold, or de minimis exemption, below which units are either too small or emit a small enough amount that they do not have to get a permit. The emissions of the TFF are insignificant and expected to be below de minimis levels.

Emissions data was collected throughout Phases 1-3 in order to demonstrate that emissions will not have an impact on siting the TFF based on environmental restrictions.

Table 22: Stack Emissions Summary Range Scrap Results

	CO (ppm)	NOx (ppm)
Average Recorded emissions levels	24	47

For example, de minimis requirements in the state of Ohio say that an air contaminant source is given a de minimis exemption unless "the potential emissions of any one of the following exceeds ten pounds per day: particulate matter, sulfur dioxide, nitrogen oxides,

organic compounds, carbon monoxide." [1] The state of Utah gives an exemption for sources that emit less than 10 tons per year of hazardous pollutants, which corresponds to a level of 55 lb per day[2]. Obviously, exemption levels will vary from state to state and users of this technology should contact their local Bureau of Air Quality for permitting information. The average emission levels from this demonstration are summarized in Table 23 and Table 24.

Table 23: Stack Emissions Rates per day compared to de minimis limits

	Mass per day if run at maximum throughput (lb/ day)	OHIO de minimis limit (lb/ day)	UTAH de minimis limit (lb/ day)
CO	.58	10	55
NO_x	1.84	10	55

Table 23 shows the average output of the furnace being operated at its maximum throughput. Seven cycles corresponds to the maximum number of tests that can be accomplished per day. Clearly, the emissions are below these de minimis levels.

The category of target debris was added as a courtesy to Eglin. The main purpose in this particular testing was to demonstrate that target debris could be handled by the TFF. As shown in Table 24, the reported CO levels were slightly elevated while flashing the particular target debris which was flashed. It is assumed that these higher CO levels were due to the burning of residual oils, grease, and/ or other combustible material on the target debris. It should be noted that this CO value is a single reading and represents more of a worst case number. It is anticipated that the CO emission rates over the entire flash mode or even the fifteen minute rolling average would be much lower.

Table 24: Stack Emissions Rates Target Debris

	CO (ppm)	NO_x (ppm)
11	160	35
12	212	48

The NO_x levels were similar to that of the range scrap but the CO levels were significantly higher. At 212 ppm, carried out through 7 cycles, the TFF would produce 5.13 lb of CO. This is still well below de minimis levels. Permits are therefore not anticipated to operate the TFF, even for flashing target debris.

[1] http://www.epa.state.oh.us/dapc/regs/3745-15/3745_15.html
[2] http://www.airquality.utah.gov/PERMITS/pmtinfo.htm

5 COST ASSESSMENT

5.1 Cost Reporting

The major cost drivers for using the TFF to flash scrap material include the following:

- Capital Cost of the Furnace
- Maintenance of the furnace and baskets
- Labor
- Fuel
- Price of Scrap Metal

The furnace has an estimated life expectancy of 20 years. With this life expectancy, the annual cost of the furnace is $22,500. If running the furnace at maximum throughput, the capital cost of the furnace will be equivalent to $5.14 per ton.

If running the furnace at maximum throughput, it is recommended to have 1 day set aside per month to do minor maintenance activities such as placing grease in the bearings, cleaning out the burners, etc. Labor for these activities will be about $1,000 a month. It is estimated that after 5 years the carbottom refractory will need to be repaired. This will cost approximately $25,000. If the TFF were not running at maximum throughput, maintenance will not need to be performed as often. Therefore costs are measured against material processed. The baskets will be under severe stress. If running at maximum throughput, the average basket is expected to need to be replaced every other year. However, actual basket life can only be determined with extended usage. The estimated basket cost per ton of scrap material flashed is $4.80 per ton assuming a basket life of 1250 tons of scrap flashed (1000 flashing cycles). Estimated Total Maintenance costs are summarized as follows: $12.80 per ton of material flashed.

The cycle process times and requirements were monitored during this demonstration and from this, the recommended labor rates were determined. For an average 8-hour day, labor costs will be $880, including one TFF operator, one skilled forklift operator, and two additional laborers, Reference Table 5 in Section 2.3.2. In that time, 17.5 tons can be flashed for a labor cost of $50.28 per ton.

In addition to labor, the fuel consumption was monitored. Assuming that the cost of fuel remains at $2.20 cost per gallon, the cost of #2 fuel-oil per ton are $25.96 per ton. In addition, propane is $0.40 per ton. Total Estimated fuel costs are $26.50 per ton.

Currently, scrap metal dealers in Salt Lake City, UT are buying scrap steel at $10 per ton and scrap aluminum at $0.20 per pound ($400 per ton). Realizing that most range scrap is made up of primarily steel, the operating cost will be reduced $10 per ton. However, with some scrap piles, a substantial amount of aluminum is included. In this

demonstration, 120 mm tank rounds were loaded with aluminum, creating aluminum ingots upwards to 200 lb per basket. A 200 lb aluminum ingot will be able to be sold to a scrap metal dealer for $40. This drives the operating cost down substantially, especially for ranges with substantial amounts of aluminum in their scrap like Eglin AFB; see Figure 37 and Table 26.

Figure 37: Cooled aluminum ingot from tank round tests

Operating costs include labor, fuel, and scrap metal costs. They are summarized in Tables 24 and 25:

Table 25: Operating Costs for scrap which is essentially 100% steel

	Cost per ton	Cost per lb
Labor	$50.30	$0.025
Fuel	$26.50	$0.013
Steel Scrap Price	$10.00	$0.005
Total	**$66.80**	**$0.033**

Table 26: Operating Costs for scrap which is 90% steel and 10% aluminum

Operating Costs for a load with 90% steel 10% aluminum		
	Cost per ton	Cost per lb
Labor	$50.30	$0.025
Fuel	$26.50	$0.013
Aluminum Scrap Price	$40.00	$0.020
Steel Scrap Price	$9.00	$0.005
Total	**27.80**	**$0.014**

Table 25 and Table 26 show that scrap material can be processed as low as $27.80 per ton with loads that are made up of 90% steel and 10% aluminum. With loads that are made up of 100% steel, the material can be processed as low as $66.80 per ton.

Adding maintenance costs and amortizing the capital cost of the furnace, the overall costs will increase slightly less than $20.00 per ton, see Table 27 and Table 28.

Table 27: Overall cost 100% Steel Load

	Cost per ton	Cost per lb
Operating	$66.80	$0.034
Maintenance	$12.80	$0.006
Furnace Capital Cost (maximum throughput)	$6.00	$0.003
Total	**$85.60**	**$0.043**

Table 28: Overall cost 90% Steel and 10% Aluminum Load

	Cost per ton	Cost per lb
Operating	$28.75	$0.014
Maintenance	$12.80	$0.006
Furnace Capital Cost (maximum throughput)	$6.00	$0.003
Total	**$46.60**	**$0.023**

Table 29: Cost Summary of Flashing Range Scrap with Operating Parameters

START-UP COSTS	Site Characterization	NA
	Mobilization	NA
CAPITAL COSTS	Capital Equipment Purchase	Furnace - $450,000 Baskets – 8 baskets at $4,000 a piece. 4 trays at $2,000 a piece
	Ancillary Equipment Purchase	Fuel Tank – depends on the size of the tank wanted
	Modifications	NA
	Structures, Installation	NA
	Engineering	NA
OPERATING COSTS Direct Environmental Activity Costs	Capital Equipment Rental	NA
	Ancillary Equipment Rental	NA
	Labor	$50.29 per ton
	Supervision	Included in Labor
	Site Setup	$2,000
	Site Survey	Included in Site Setup
	Processing Cost per Ton	$50 - $90 per ton depending on the material make-up of the scrap
	Digging	NA
	Operator Training	$1,000
	Maintenance	$12.80 per ton. This maintenance includes furnace maintenance and also basket replacement estimates
	Utilities	NA
	Raw Materials	NA
	Process Chemicals	NA
	Consumables, Supplies	$26.50 per ton based on $2.20 per gallon fuel cost
	Residual Waste Handling	Direct Sale
	Offsite Disposal	Direct Sale
	Sampling and Analysis	NA
Indirect Environmental Activity Costs	Environmental and Safety Training	Included in Operator Training
	Waste Manifesting (if any)	NA
Demobilization		$2,000

5.2 Cost Analysis

The maximum throughput was developed upon analyzing the process parameters, see Section 4.3.3. The TFF should be able to process 6-7 loads per day with 7 loads being the norm. Each load should include up to 5,000 lb of range scrap. This allows time for maintenance, lunch, and work breaks. If this rate is maintained throughout the year, between 3,750- 4,375 tons of range scrap can be processed annually. This throughput is the basis for this cost analysis.

Life cycle cost for the technology was based on the cost of the Transportable Flashing Furnace, $450,000. Its estimated life is 20 years. Operating at maximum throughput, the amortized cost of the furnace is $5.14 per ton.

Demobilization costs are based on two workers labor to take-down and set-up the TFF. This should take no more than one day. Transportation costs are also estimated although they will vary depending on the needed travel distance and time.

Maintenance costs are based on the required maintenance of the TFF and the baskets. It is estimated that with a full-scale operation, one day a month should be set aside as a maintenance day and used to perform all maintenance activities. With a reduced operation, this may only need to be bi-monthly or tri-monthly. It is estimated that with labor and time, that every maintenance day will cost approximately $2,500. With a full-scale operation, car-bottom repairs will need to be done every five years. This can cost approximately $25,000. With the full-scale operation and this cost estimate, this cost was divided over five years and included with maintenance. Basket costs are considered with maintenance costs, because it is anticipated that they will need to be replaced after approximately 1000 loads. If 8 baskets are purchased at the onset of use, and operated at maximum throughput, about 4 baskets per year would need to be replaced.

6 IMPLEMENTATION ISSUES

6.1 Environmental Checklist

The range scrap to be thermally decontaminated to a 5X level in the TFF is not considered to be either a waste or to be hazardous and therefore RCRA regulations are not applicable. The range scrap is being decontaminated for safety reasons prior to being sent off-site to be recycled and is therefore not considered to be a waste. The range scrap has the potential to be contaminated with trace quantities of explosives. It is important to note that although explosives are listed as a D003 waste due to the characteristic of reactivity the range scrap itself does not exhibit the D003 characteristic and therefore it is not classified as hazardous by RCRA. The TFF does not require any RCRA permits to operate.

The TFF is used to thermally decontaminate metal debris by heating them up to 650^{o}F and holding at that temperature for at least 10 minutes. The typical load is almost all metal and contains virtually no combustible material. The TFF therefore does not generate any appreciable quantities of combustion products. If there are low quantities of potential combustible residues such as motor oils or grease on scrap vehicle parts, the cooling air fan on the TFF can be started during the heating process. This will ensure that adequate combustion air is available for complete combustion and will minimize the potential formation of carbon monoxide. Typically, the only potential permit required to operate the TFF is an air permit. Therefore, contact with the local Bureau of Air Quality is necessary. Time to receive this permit or anticipated de minimis exemption for most states should not be significant, because the potential emissions are essentially only those from the burning fuel and are so low that the TFF is under de minimis levels and its emissions are considered or classified as “insignificant.”

6.2 Other Regulatory Issues

Prior to the demonstration, contact was made with the Interstate Technology Regulatory Council (ITRC) to ensure that necessary emissions data is acquired to satisfy as many states as practicable. This document, with its associated emissions data, will be given to them for review.

6.3 End-User Issues

Communication and coordination with ESTCP, Eglin AFB, and BAE Systems was necessary throughout the demonstration. On June 16, 2005, EDE successfully demonstrated the technology to ESTCP personnel, potential clients, and Eglin AFB management at the demonstration site.

In addition, EDE has presented two papers regarding this technology and will present one more in November including:

- Ralph Hayes – San Antonio. Presented Aug 12, 2003 at 8th Annual Joint Services Pollution Prevention and Hazardous Waste/ Management Conference and Exhibition in San Antonio, TX.

- Chad Lasson – "Decontamination of Test Range Metal Debris using a Transportable Flashing Furnace." Presented May 12, 2005 at National Defense Industrial Association in Reno, NV.

- Ralph Hayes – "Transportable Flashing Furnace (TFF) Demonstration." Will be presented November 29-30, 2005 at 14th Demil Users Group Meeting in Rock Island, IL.

6.3.1 Procurement Issues

Baskets will need to be purchased from EDE. Commercially available baskets were not able to withstand the heat structurally and could not handle the molten material.

A separate platform design needs to be developed and implemented for larger pieces of target debris such as tank guns, automobile pieces, etc.

7 REFERENCES

1. Army Regulation 385-64, "Explosives Safety Program" and DA Pamphlet 385-64, "Ammunition and Safety Standards."

2. AFMAN 91-201, "Explosive Safety Standards."

4. Department of Army Technical Bulletin (TB) 700-4. "Decontamination of Facilities and Equipment." October 31, 1978.

3. DOD Directive 5160.65, "Single Manager for Conventional Ammunition," November 17, 1981.

4. DOD Manual 5160.65M, "Implementing Joint Conventional Ammunition Policies and Procedures," Chapter 13, Paragraph F, "Demilitarization and Disposal – Developing Technical Procedures and Instructions." April 1989.

5. DOD 4160.21-M and DOD 4160.21-M-1, "Defense Demilitarization Manual." October 22, 1981.

6. DOD 6055.9 – STD. "DOD Ammunition and Explosives Safety Standards." July 1999.

7. Executive Order 12088, "Federal Compliance with Pollution Control Standards.

8. Letter from the Commander, Naval Facilities Engineering Command. 2 May 2003.

9. Memo from Naval Ordnance Safety and Security Activity. 2 May 2003.

10. Memorandum for C, EQD. "Solid Waste Incinerator Regulations and Flashing Furnaces." 15 May 2001.

11. Memorandum for Inspector General of the Department of Defense Et. al. from the Office of the Under Secretary of Defense, Re: recycling of Firing-Range Scrap consisting of Expended Brass and Mixed Metals gleaned from Firing-Range Clearance through Qualified Recycling Programs. 15 May 1998 (http://enviro.nfesc.navy.mil/esc426/Dcuments/moms2.htm)

12. OPNAV Instruction 3500.39A, Operational Risk Management (ORM).

13. Parsons-UXB Joint Venture, 2003. Phase II Report on Process Verification and Quality Control for the Kaho'olawe Car Bottom Thermal Processing Unit for Scrap Material Processing. February, 2003.

14. UXB International Inc. 2002. Report on Process Verification and Quality Control for the Kaho'olawe Car Bottom Thermal Processing Unit for Scrap Material Processing. October 2002.

15. Ohio Air Quality Regulations. http://www.epa.state.oh.us/dapc/regs/3745-5/3745_15.html

16. Utah Air Quality Regulations. http://www.airquality.utah.gov/PERMITS/pmtinfo.htm

8 POINTS OF CONTACT

Table 30: Contact Information

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